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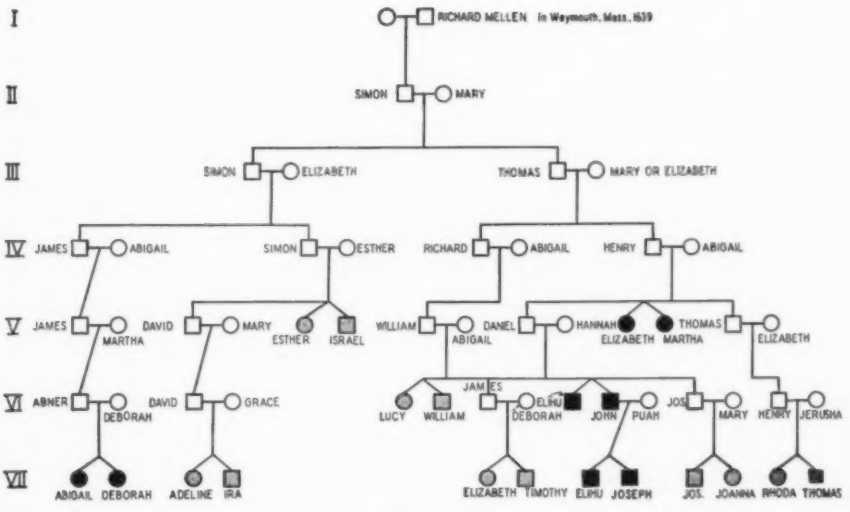

A TWINNEY PEDIGREE

(SEE PAGE 367)

Are the Dionne Quintuplets Identical?

Democratic Eugenics Versus Eugenics by Decree

May Susceptibility to "Blood-Poisoning" Be Inherited?

A Sex-Difference in Plumage-Color in the Goose

"Somatic Polyploidy" in Metamorphosis

Inheritance of "Opalescent Dentin"

Cytology of Sheep-Goat Hybrids

The "Calico" Foxhound

VOLUME 29 SEPTEMBER, 1938 NUMBER 9

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CONTENTS

GENETICS OF QUINTUPLETS
By John W. MacArthur 323

CORN AND EUGENICS
Excerpts from the Spragg Memorial Lecture 331

SEXUAL DIMORPHISM IN THE DOWN-COLOR AND ADULT PLUMAGE OF GEESE
By C. D. Gordon 335

"LAZINESS" IN MAIZE DUE TO ABNORMAL DISTRIBUTION OF GROWTH HORMONE
By J. van Overbeek 339

HEREDITARY SUSCEPTIBILITY TO SEPSIS
S. Edmund Stoddard 341

COMPARATIVE STUDIES ON THE CHROMOSOME NUMBERS IN SHEEP, GOAT, AND SHEEP × GOAT HYBRIDS
By R. O. Berry 343

PROPHASE CHROMOSOME BEHAVIOR IN THE DIVISION OF CELLS WITH MULTIPLE CHROMOSOME COMPLEXES
By C. A. Berger 351

HEREDITARY OPALESCENT DENTIN
By H. C. Hodge and S. B. Finn 359

MERLE OR CALICO FOXHOUNDS
By J. McI. Phillips and E. D. Knight 365

TEN PAIRS OF TWINS
By Ida M. Mellen 367

Reviews and Notes

BOOKS RECEIVED 329
CYTOLOGY FROM FRUITS TO NUTS 337
THE SEVENTH INTERNATIONAL BOTANICAL CONGRESS 338
INCA BULLDOGS 350
GENETICS OF FLAX AND HEMP 350
LUDWIG PLATE'S LAST VOLUME (Rev. of *Vererbungslehre*) 357

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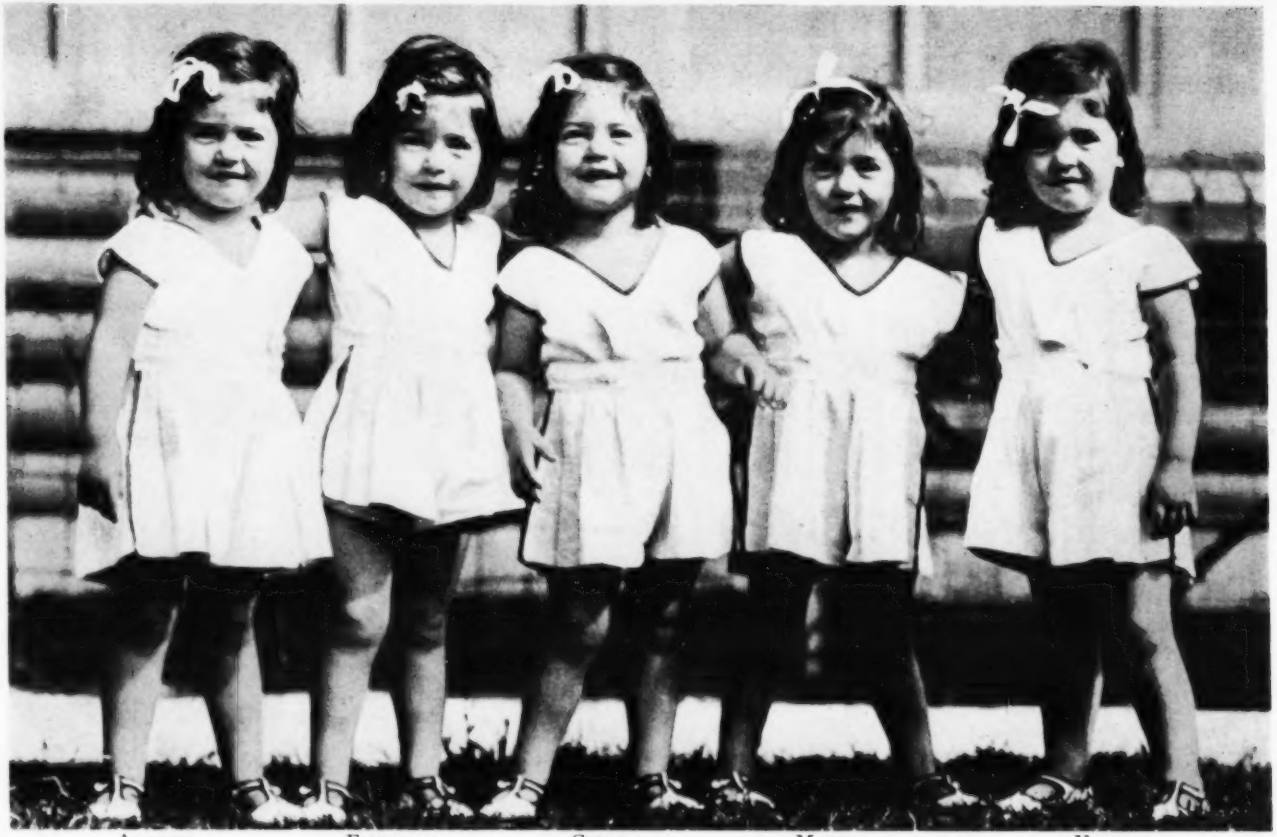

ANNETTE EMILIE CECILE MARIE YVONNE

THE DIONNE QUINTUPLETS AT THREE YEARS OF AGE

Frontispiece

Comparisons between pairs of the Quintuplets show that on the averages the resemblance between all five is as clase in such diagnostic traits as hair and eye color, blood groups, fingerprint patterns, etc., as is found between identical twins. Such comparisons do not single out any of the five as being distinct from her sisters. This confirms conclusions from other data that these Quintuplets are identical. Genetically any of them might be any of her five sisters. (Copyright, NEA Service, Inc., 1937.)

GENETICS OF QUINTUPLETS

I. Diagnosis of the Dionne Quintuplets as a Monozygotic Set

JOHN W. MACARTHUR
Department of Biology, University of Toronto

THE increasing number and enlarging scale of twin studies by biologists, psychologists and educators the world over are indications of the widespread realization that twins offer an exceptionally favorable material for the investigation of a number of fundamental problems concerning the nature of the action of hereditary factors and environmental influences in determining the various physical and mental characters in man. Moreover, the relative value for this purpose of triplets, quadruplets and quintuplets undoubtedly increases progressively as the number of individuals in the set rises toward five, and it is only the great rarity of the higher multiple births which prevents them from becoming the chief subjects of such studies.

An especial interest thus attaches to the Dionne quintuplets, being studied genetically by the writer and Dr. Norma Ford, since they are the only set of five that has survived long enough for any very extensive observations to be made. This interest is only the more increased when it is seen that they are in all probability monozygotic, and apparently supply an ideal set-up for further biological and psychological observations of value.

Since the odds are in general greatly *against* rather than *for* any particular quintuplet set being monozygotic, and since the proper understanding and interpretation of the considerable variation between these quintuplets in their physical and psychical traits depends upon the correctness of the diagnosis made, we are naturally expected to produce sufficient concrete and verifiable evidence that the Dionne set are really all "identical."

The Problem

A quintuplet set composed of five girls may originate from one, two, three, four or five ova, and in any of seven ways. In Table I, showing these possibilities, the division products of each ovum are included within brackets (as within a common chorion). The five members may be compared two at a time in ten different combinations; the results expected from such comparisons (last columns) vary according to the origins.

Two processes, that appear to be fundamentally unlike[8], may thus be involved: (1) the liberation and successful fertilization and implantation of extra eggs (polyovulation) or (2) the division of one or more fertilized eggs or embryos to form two or more foetuses each (true "twinning"). The quintuplets would thus be all "fraternal" if they arose from five separate ova; all "identical" if produced by division of one zygote; and mixed (some pairs

TABLE I. Possible Constitution of Quintuplet Sets

Number of original ova	Constitution of the set					Of the 10 possible couplets: Number identical	Number fraternal
1	(♀♀♀♀♀)					10	0
2 a	(♀♀♀♀)	(♀)				6	4
b	(♀♀♀)	(♀♀)				4	6
3 a	(♀♀♀)	(♀)	(♀)			3	7
b	(♀♀)	(♀♀)	(♀)			2	8
4	(♀♀)	(♀)	(♀)	(♀)		1	9
5	(♀)	(♀)	(♀)	(♀)	(♀)	0	10

Quintuplets are identical. Genetically any of them might be any of her five sisters. (Copyright, NEA Service, Inc., 1937.)

fraternal, others identical) if derived from two, three or four ova.

The basic principle adopted is that multiple births are in a sense all comparable, and the analysis of a quintuplet set advisedly follows the methods found successful for quadruplets[15] and triplets[14,26], as these in turn have taken as their model the standards and norms established by the more extensive and thorough studies of twins. From this point of view a triplet set consists of three pairs of individuals, quadruplets of six, and quintuplets of ten pairs. The specific problem then resolves into one of determining the monozygosity or dizygosity of each of the ten pairings possible in the Dionne set. All the accumulated knowledge of twin diagnosis from time to time reviewed in this JOURNAL[11,21,22,25,27] and elsewhere (in the appended literature) may thus be brought to bear.

The gist of these findings is that twin diagnosis may be made fairly dependable, but is necessarily largely a matter of weighing probabilities, Mendelian and otherwise, there being no simple specific test or absolutely decisive and infallible diagnostic mark, which at once distinguishes fraternal from identical pairs. The difficulty is at present somewhat magnified in the Dionne case because of the extreme youth of the children[30] and the incompleteness of some of the observations on the family.

We have especially emphasized the necessity, whenever genetic questions are involved, of including sibs from the same family to serve as known *fraternal controls* to compare with the members of the set to be diagnosed[18,29,30]. Since the numerous pairings within this set also act as mutual checks the diagnosis offered is probably more reliable than that of twins studied apart from the remaining members of the family.

Why the Dionne Quintuplets are Believed to be Monozygotic

Employing the diagnostic criteria accepted as most reliable for separation of identical and fraternal twin pairs, we have found that by each method currently in use and by the newer quantitative method developed from dermatoglyphics[16] the Dionne quintuplets conform to the standards set for identical pairs; all the tests have lead to the same conclusion — that the set is monozygotic. The following samples of the evidence, given more fully elsewhere[17], illustrate the nature of the data and methods used.

1. Structure of the Placenta and Foetal Membranes

Identical twins[4,7,30] and triplets[27] have typically only one placenta, one chorion, and a common anastomosing circulation. From Dr. Dafoe's brief descriptions of the afterbirth in the Dionne case[4,5] there was evidently a single large placenta, one investing chorion, and probably five separate amnia and five cords attached close together in a ring. If the contents of one chorion are derived from one ovum, this is additional evidence that the set is uniovular. Incidentally, there is a distinct suggestion[4,5,17] that the set may originally have consisted of six members, the sixth embryo aborting very prematurely. Since the afterbirth was destroyed, the main reliance in diagnosis is necessarily placed on the study of inherited characters.

2. Similarity of the Quintuplets in Genetic Characters

Individuals of a monozygotic pair or set being duplicates in genotype, are therefore alike in all phenotypic characters so far as these are under hereditary control; thus they (like the Dionne quintuplets) are the same in sex and blood groups, much alike in faces, eyes, hair, etc., and similar though varying in finger prints, stature, weight and other physical as well as the mental measurements[7,13,16,24,28,29,30]. On the contrary, from the nature of the hereditary mechanism, fraternal twins, arising like ordinary sibs from separate fertilized eggs, quite invariably differ in some respects in genotype, and (like the Dionne sibs) seldom agree in any considerable number of independently inherited characteristics that depend for

their expression on numerous randomly distributed genes.

a.—Facial features. Scientific evidence supports in the main the popular view that degree of likeness in faces is a fairly trustworthy guide in separating the two types of twins.[7,19,28,29,30,31] The confusingly close facial resemblance of all the Dionne quintuplets at three years of age (Frontispiece) is convincing evidence that they probably all carry the same genes controlling the innumerable details of the facial features (mouth, lips, cheeks, eyes, ears, hair, etc.). There are enough individual differences, however, so that the children themselves, the nurses, and some others have readily learned to recognize each of the five.

The quintuplets form a comparatively homogenous group (Table II) in a family where the parents differ in many features, and the sibs vary over a wide range in hair color (fair to dark brown), hair shape (straight to very curly), iris color (light to dark brown), form of face, ears, etc. Thus as far as the polysymptomatic method of Siemens,[28] Verschuer,[30] Muller and others is applicable it indicates monozygosity.

Further observations are planned on the *M-N* blood groups, *P.T.C.* taste tests and electrocardiograms — to mention only a few laboratory tests of a physiological nature. The data from the physical measurements, the progress of ossification of the bones, and the eruption of the teeth will receive separate treatment.

b.—Finger, palm and sole prints. The hereditary dermal ridge characters have a particularly high value in diagnosis, the ridges being fixed as to number and direction long before birth and not changing appreciably with age, environment, or condition of health.[31]

Beneath the expected general family likeness of the hand and foot prints in the Dionne sibship, an especially close resemblance is demonstrable among all the quintuplets. Their finger prints for example (Table III) are as like as in most identical twins, although, of course, sufficiently different in type, size, and minutiae of patterns to make easy their individual identification by the police system. The quintuplets' palm and sole prints, also reproduced and described in the fuller account,[17] repeat some rare features; each of the five has one or two whorls among her palmar interdigital patterns; this occurs in none of the three

TABLE II. Characteristics of the blood groups, eye, skin, and hair of the quintuplets. Iris color was matched with Saller's chart; iris pattern with Hesch's series; and skin and hair colors with Schultz's tables.

	Blood Group	Iris Color	Iris Pattern	Eye Refractive Error	Eye Lashes	Eye Brow	Hair Color	Hair Form	Hair Whorl	Skin Color
E	0	M_4	9	+1.00	long curled dark brown	light brown	8	wavy	counter clock-wise	3
Y	0	M_4	9	+ .75	long curled dark brown	light brown	8	wavy	counter clock-wise	3
C	0	M_4	9	+ .75	long curled dark brown	light brown	8	wavy	counter clock-wise	3
M	0	M_4	9	+1.25	long curled dark brown	light brown	8	wavy	clock-wise	3
A	0	M_4	9	+ .75	long curled dark brown	light brown	8	wavy	counter clock-wise	3

sibs and but seldom in the general population. Uncommon characters found on all ten feet of the quintuplets are a mild syndactyly of the second and third toes,[3] and a rather peculiar thenar pattern complex.

Comparison of three finger print characteristics among the quintuplets (10 pairs) and between sibs of different ages (18 pairs) in the Dionne family, show how much more alike the former are (Table IV).

The use of twin series as norms is illustrated in just one case. The 50 identical and 50 fraternal twin pairs so intensively studied by Newman[19] were found by his classification to differ in ridge counts as shown in Table V. By precisely the same system the Dionne quintuplet pairs differed by from 0 to 3 units (average = 1.4) and the sibs by from 4 to 34 (average = 16.3) units. From the distributions in Table V it is seen that a pair with a difference of 3 or less is 11 times as likely to be identical (11/12) as fraternal (1/12); the chances of three of the set being fraternal is lower (1/12),[2] of four (1/12),[3] etc. Assembling such evidence from character after character shows how slight is the combined probability of any of the quintuplets being fraternal.

The data in the last columns of Table IV are used in Stock's criterion; by his B4 method,[29] all the quintuplet pairs are monozygotic, for they have at least 7 similar patterns on corresponding fingers, or more than on the fingers of own left and right hands. This was not the case with any of the 18 sib couplets.

TABLE III. Finger pattern types, and ridge counts read from left to right, and total quantitative values for each hand of the quintuplets; Emilie (E), Yvonne (Y), Cecile (C), Marie (M), and Annette (A), and three older sibs, Ernest (Er), Rose (R), and Therese (T).

	Left Fingers					Quantitative Value		Right Fingers				
						L	R					
						total						
E	U	U	T.A.	U	U			W^{du}	U	U	R	U
	0–4	0–10		0–12	0–18	44	55	19–11	12–0	10–0	0–8	6–0
						99						
Y	U	U	U	U	W^{du}			W^{du}	T.A.	U	U	U
	0–7	0–12	0–11	0–11	10–17	58	44	18–10		14–0	6–0	6–0
						102						
C	U	U	U	U	U			U	U	U	R	U
	0–6	0–4	0–12	0–7	0–18	47	53	19–0	11–0	12–0	0–6	5–0
						100						
M	U	U	U	U	U			U	U	U	U	U
	0–7	0–11	0–8	0–10	0–16	52	49	18–0	7–0	12–0	7–0	5–0
						101						
A	U	U	U	U	U			U	U^{ta}	U	R^{w}	U
	0–7	0–10	0–9	0–9	0–16	51	50	18–0	3–0	10–0	0–12	7–0
						101						
Er	U^{a}	U^{w}	U	U	U			W	U	U	U	U
	0–2	0–7	0–5	0–4	0–13	31	47	21–14	10–0	4–0	8–0	4–0
						78						
R	U	U	U	R^{a}	U			U	U	U	U	U
	0–3	0–7	0–10	1–0	0–7	28	41	13–0	4–0	13–0	8–0	3–0
						69						
T	U	U	U	U	U			U	U	U	U	U
	0–8	0–14	0–6	0–12	0–20	60	79	24–0	16–0	11–0	17–0	11–0
						139						

TABLE IV. Differences found between pairs in the Dionne family in:

	Total ridge counts		Pattern indices (%)		Finger patterns (out of 10)	
Pairs	Average	Range	Average	Range	Average	Range
Quintuplets	1.4	0–3	2.1	0.1–3.4	2.9	1–4
Sibs	32.7	9–70	30.6	1.5–49.5	6.3	5–8

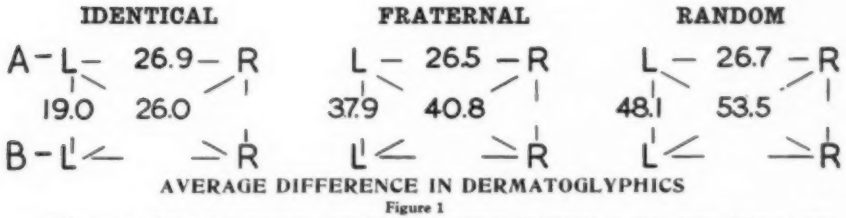

Figure 1

This graph shows the average cumulative percentage difference in the dermatoglyphic patterns found in fifty pairs of identical twins, fifty pairs of fraternal twins, and 150 pairs of randomly selected (unrelated) individuals. The pairs are designated *A* and *B*. The interpair comparisons are presented in the vertical and diagonal figures. This shows identical twins to be about twice as similar as fraternal twins, and about two and a half times as alike as randomly selected pairs.

In the distribution of ridge counts over the various fingers (Table III) the genotype indicated by Bonnevie's method[1] is *VvRRUU* for each quintuplet, and *VVRrUU*, *vvRRUU* and *VvRRUU* for the three sibs; despite segregation in the family for *Vv* and *Rr* the same genotype is repeated through the entire set.

An objective and generally reliable method for diagnosis devised by the author[16] sums up in one percentage the average amount of difference shown in finger patterns and ridge counts, palm line courses and patterns collectively; and combines the most valuable features of the polysymptomatic method[28] with the diagnostic procedures used by Bonnevie,[1] Komai,[12] and Newman.[19-22] The characteristics of identical, fraternal and random (unrelated) pairs are shown in Figure 1. In every pair (*A* and *B*) three comparisons are made: one intra-individual, measuring (*a*) the left-right or *bilateral* difference (*L-R, L'-R'*), and two inter-individual, comparing (*b*) same-side, or *homolateral*, (*L-L', R-R'*) and (*c*) opposite-side or *heterolateral* hands (*L-R', R-L'*).

TABLE V. Number of pairs differing in quantitative value (ridge counts) by 0, 1 — 70 units.

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16–20	21–30	31–40	41–50	51–60	61–70
50	Identical twins	12	8	6	7	6	1	4		2		1				1	1			1			
10	Dionne quintuplets	3	3	1	3																		
50	Fraternal twins			2	1		1	1		3	4		3	2	2	2	1	5	8	7	4	2	2
18	Dionne sibs					1					1		1	3	1		1	7	2	1			

TABLE VI. Showing the resemblance of the Quintuplets to identical twins in their finger and palm print characters. Per cent differences between hands of pairs in respect to: (1) ridge counts of the fingers, (2) finger pattern types, (3) palm lines and axial triradii, (4) palmar patterns, and (last column) the average of all the differences.

Hand comparison	Pairs	(1)	(2)	(3)	(4)	Average
Bilateral	Identical twins	10	26	42.5	30	26.9
	D. Quintuplets	11	26	36	52	31.2
	Fraternal pairs	11	26	36.4	33	26.5
	D sibs	24	20	44	46	32.7
Homolateral	Identical twins	8	19	28	21	19.0
	D. Quintuplets	9	26	30	34	24.7
	Fraternal pairs	30	44	41.5	36.5	37.9
	D. inter sib	26	23	45	54	37.4
Heterolateral	Identical twins	9	25	40.4	30	26.0
	D. Quintuplets	7	31.5	33	43	28.8
	Fraternal pairs	30	44	47.5	42	40.8
	D. inter sib	29	24	48.9	63	40.7

These relations help detect such asymmetry reversal as occurs, allow an analysis of variance,[16] and provide probably the most reliable norms for diagnosis. Particularly useful are the facts that the homolateral differences are, as a rule, very low in identicals (and lower than the bilateral difference), but high in fraternals (higher than the bilateral).

When applied to the quintuplets pair by pair, the method indicates Emilie and Yvonne to be like identical twins; also Yvonne and Cecile, Cecile and Marie, Marie and Annette; so that considered in this or any other order the set are linked together to form an inseparable unity, in which no member is odd or exceptionally (i.e. fraternally) different; and no two pair off regularly as unlike the others.

The general results of the study of the finger and palm prints are found in Table VI, where the quintuplets align themselves with identical twins, while the sibs are, of course, like fraternals.

These data harmonize well with the results already obtained not only with twins, but also with triplets and quadruplets[16] (Table VII). Identical pairs show about the same degree of likeness in these characters whether they are taken from twins or from identical multiple birth sets.

Evidence as to the Order of the Twinning Divisions

It would be interesting to secure evidence disclosing the precise order of separation of the five (or six) embryos and their former positional relations at successive stages of development. There are some asymmetry reversals in Marie (hair whorl, etc.) and in Emilie, who alone is left handed; on such grounds[22] these two might be considered products of a last (third) division. A close scrutiny of special resemblances within the set also suggests some effect of delay in development possibly referable to prior intrauterine handicaps in vascular supply, sites of attachment, etc. The most retarded members, Marie and Emilie, may be somewhat more alike because of this, the other larger ones following in the general order of likeness: E—M—C—Y—A. Up to the present, there seems to be some association between the physical retardation and the mental, social and personality ratings, reported by Blatz, Millichamp and others (in the later sections of the book[17]).

3. Inheritance and Multiple Births

Fairly convincing evidence is available for twins,[7, 8, 9] triplets[26] and quadruplets,[2] that polyovulation (liberation of additional eggs) is an inherited character with a late age expression in mothers, while true twinning (division of eggs) occurs pretty much at random among births and is not thus associated with age and parity of the mother.

The same quite apparently holds in

TABLE VII. Showing by the quantitative method the essential similarity (1) on the left, of identical pairs in twins and in triplet, quadruplet, and quintuplet sets, and (2) on the right, of fraternal twins or sib pairs throughout the multiple birth series.

	Identical Pairings	Average Per Cent Differences				Fraternal Pairings	Average Per Cent Differences		
No.	From	Bi-lateral	Homo-lateral	Hetero-lateral	No.	From	Bi-lateral	Homo-lateral	Hetero-lateral
50	Identical twins	26.9	19.0	26.0	50	Fraternal twins	26.5	37.9	40.8
					62	Single sibs	29.2	39.8	44.1
9	Identical triplets (Johnson, Burling, Reddall)	27.4	23.5	28.4	62	Mixed triplet sets and sibs	29.6	41.1	41.9
6	Identical quadruplets (Morlok)	28.2	21.25	29.2	5	A mixed quadruplet set (Keys)	20.2	39.6	36.3
10	Identical quintuplets (Dionne)	31.2	24.7	28.8	18	Quintuplet sibs	32.7	37.4	40.7

quintuplets. Among the 45 most completely reported cases of quintuplet births mainly from the medical literature it appears that at least two or three (probably some other) sets, counting the Dionnes, are monozygotic.[10] These were born to younger mothers than were the definitely fraternal (mixed sex) sets; in the sets believed on other grounds to be identical there was no repetition of twins or other multiple births at other pregnancies, and little evidence of twin production in the parents' families. In the fraternal sets, on the other hand, there was a high incidence of twin production and of positive family histories.

Conclusion

Besides being the same in sex and blood group, and very similar in facial features, eyes, hair, ears, etc., the Dionne quintuplets are also as much alike in finger, palm and sole prints as are identical twins, and show further evidence of being monozygotic in the youth of the mother and the negative history of twin production in the immediate families.

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CORN AND EUGENICS

Excerpts from the Spragg Memorial Lecture, "Corn Breeding Experience and Its Probable Eventual Effect on the Technique of Livestock Breeding," by Secretary of Agriculture Henry A. Wallace, at Michigan State College, April 21, 1938

The Frank A. Spragg Memorial Lectures were established at Michigan State College to honor a distinguished plant breeder who, during eighteen years at East Lansing, made many contributions to American Agriculture. Rosen rye and Worthy oats are two of the many important varieties originated by Dr. Spragg. The lectures are issued in booklet form by the Department of Farm Crops of Michigan State College.

The 1938 lecture is noteworthy because it carries forward the idea of "greater boldness in experiment" which Secretary Wallace stressed as a vital need in the 1936-7 "Genetic Yearbooks." Here he speculates with realistic boldness on ways whereby corn genetics may fertilize the formal and perhaps somewhat genetically sterile concept of "pure breeding" in livestock. The closed studbook has often meant only "purebred scrubs"; but closed herds, even though their members might win no show-ring prizes, may be the basis of "controlled heterozygosis," which will give us "crossed hogs" and "crossed cows" as vigorous, uniform and productive in their way as the best of the maize hybrids which are today sweeping the Corn Belt. On the human side, Secretary Wallace effectively debunks the "biological bedtime stories" of Aryan mythology, and he has a heartening message for eugenic thinking in a democracy. Even though maize teaches us that the genetic heritage cannot be ignored, it gives us little hope of "saving the race" by attempting to control human reproduction by legislation or decree.—Ed.

Reviewing the archeological history of Indian corn, the history of last century improvement efforts, and of genetic methods since 1910, Secretary Wallace showed in what respects earlier breeding approaches were wrong or of limited value, "that corn beauty was not connected with yielding ability" and summarized the results of applied genetics in producing high yielding crosses of inbred lines in the following words:

IT seems probable that in the year 1938 there will be planted at least fifteen million acres of hybrid corn and if we have ordinary weather, the total yield of corn will be at least 100 million bushels more than would have been the case if the same acres had been planted to open pollinated corn. Under some conditions the hybrid corn will yield little if any more than open pollinated corn but under other conditions it may yield as much as 30 bushels an acre more. No one knows what causes these wide variations but we do know that under average conditions adapted hybrids will yield fully eight bushels an acre more than open pollinated corn. Also, most of the commercial hybrids have stiffer stalks than the open pollinated corn. At the present time there are very few adapted commercial hybrids for the northern Corn-Belt or the southern Corn-Belt. In time, undoubtedly, there will be plenty of good commercial hybrids for both the northern and southern Corn-Belt.

The experiment stations, the private breeders, and the United States Department of Agriculture have, during the past ten years, produced literally thousands of inbred strains of corn and hundreds of thousands of single crosses, three-way crosses, and four-way crosses. The experimental work by these various agencies probably costs, at the present time, more than a million dollars a year. Of the many thousands of inbreds produced, probably only 40 or 50 are really outstanding. An immense amount of work is now going forward to improve these various inbreds by back-crossing, so that their respective strong points can be retained and the weak points eliminated.

From now on the rate of progress in hybrid corn will undoubtdly be much slower than during the past 15 years, but nevertheless there is certain to be progress. Looking ahead, we can be fairly certain that in 1945 there will be

well adapted commercial strains of hybrid corn for practically every section of the Corn-Belt, that will yield at least 20 per cent more than the average open pollinated corn as grown in the respective parts of the Corn-Belt in 1920. This means that on most of the farms in the Corn-Belt, the 20 per cent of the corn land which is most poorly adapted to corn and most likely to be hurt by erosion, can be taken out of cultivation and returned to grass. From an economic point of view, the significance of hybrid corn is probably greater than most of the plant breeding achievements in which the experiment stations and the Department of Agriculture have been involved.

Secretary Wallace then considered the implications of the modern approach to corn breeding on livestock breeding, "which is much in the same state as the corn breeding operations were previous to 1910." The egg-laying contest in poultry the nearest approach to yield-tests in corn, but only approximately comparable because of small numbers necessarily involved and failure to test all but the best in a flock. The score-card approach was compared with the progress so far made in sire indexes, advanced registry, etc. The difficulties of inbreeding cattle to produce "crossed cows" stressed. Possibilities of applying "controlled heterozygosis" by intercrossing inbred lines of swine.

In conclusion:

The purebred breeders under this system [of furnishing homozygous strains which when crossed give optimum hybrid vigor] would have a function many times as important to the practical farmer as is the case at the present time. I am sure that it will only be a few years until a large number of the purebred breeders will gradually shift their plans to help in an approach of this type. I am convinced the average purebred breeder has sufficient of the practical farmer in him so that he wants to cooperate to the utmost to enable the farmer to turn the minimum of grain into the maximum of satisfying meat for the ultimate consumer. Both the breeder and the farmer are interested not in show-ring ribbons but in those methods that will enable the farmer best to serve the consumer. * * *

The method which I have described here might briefly be called the method of homozygosis followed by controlled heterosis. It is only by some such method as this that the gamble can be taken out of livestock breeding. It is only by some such method as this that the purebred breeders can serve the practical farmers to the utmost. I hope the Animal Husbandry Division of the United States Department of Agriculture, the Animal Husbandry Departments of the various agricultural colleges, and the Animal Husbandry Extension Agents throughout the land can join together gradually to make it possible for animal breeding to make progress along some such lines as these. The principles can first be worked out in chickens and swine, next in sheep and dairy cows and finally in beef cattle.

The establishment about a year ago of a regional swine-breeding laboratory at Ames, Iowa, in which the Corn Belt Experiment Stations and the Department of Agriculture are cooperating is a significant step in this direction. In this laboratory intensive effort is being given to the development of strains with varying intensities of inbreeding and to the perfecting of means that will make possible the evaluation of these strains, as well as the evaluation of individual sires in the herds of breeders. * * *

In his conclusion Secretary Wallace considered the implications of genetic knowledge as it applies to human affairs:

Intelligent Approach to Eugenics Needed

We have dealt at length with the contributions that Indian corn has made to American agriculture, and to our theoretical and experimental knowledge of fundamental principles of heredity. Does our knowledge about corn have any larger message at this time, when a world is being remade before our eyes? It is easy—and very hazardous—to deduce general principles from our observation of other organisms and to

attempt to find analogies in human affairs. The history of corn and its development could easily be worked over into such a sociological bedtime story, which would have very little meaning. Nevertheless there are a few principles which may throw light on certain aspects of human affairs without straining our analogy to the breaking point.

Perhaps the clearest conclusion to emerge concerns that school of eugenic thought which hopes to bring about the millenium by sterilization of deficients and defectives. The failure of Dr. Kiesselbach's attempt to improve Hogue yellow dent corn by detasseling the sterile, the smutted, and otherwise defective plants, convinces me that it is impossible to bring about genetic improvement of the human race merely through a sterilization program. What we know about the number of generations necessary to produce homozygosity in corn, and the rigorous technique necessary to utilize the principle of controlled heterosis in crossed corn production, renders it most unlikely that human society will countenance the rigid control necessary to utilize directly an effective program of genetic improvement that could be relied upon to change the inborn nature of mankind in any reasonably near future.

These negative conclusions are as far as we can go in reasoning directly from corn to man. Something may be said of a more general nature. Corn growing is not pure genetics. The variety of corn we attempt to breed is adapted to a certain definite environment. There is no one variety of corn that is equally good all over the United States. Either consciously or unconsciously we must accept a certain environment as part of our breeding program. We must make the best of that environment if we are to get a maximum crop. It would be the height of folly to spend years in developing a superior variety of corn, and then to give no thought to culture —preparing and fertilizing the seedbed, and cultivating weeds. This adaptation to environment, and the need to control environment so far as possible to insure a crop, has clear implications in human affairs, where these same basic truths apply. The development of a high human culture is further complicated by an added dimension which does not concern us when we develop a superior variety of corn and carry it through to the harvest. With corn the problem of the breeder and grower is relatively simple, and the goal quite definite. The farmer has only such definite imponderables as the weather, insect pests, fluctuation in prices, and labor difficulties, and the health of himself and his family to consider in bringing a crop to maturity.

The hardy soul who undertakes to direct human evolution must go beyond this and consider not only the genetic make-up of the human race and the environment in which this genetic background is expressed, but he must also give thought to the kind of environment in which the human spirit comes to its best fruition. It is very clear to anyone who has studied and tried to think philosophically about man, that a eugenics program to have any significance whatever must be much more than merely applied human genetics. When we consider the almost insuperable difficulties placed in the way of the cattle breeder by such aesthetic hurdles as color and indefinite points of conformation, we realize at once that the salvation of the human race cannot come through human genetics applied by a dictator. Our problem is further complicated by the fact that while the breeder has a fairly definite ideal in mind toward which he can select, by the very nature of the case no such simple program will do for man, where our need is for diversity rather than uniformity.

It is impossible to follow the thought very far at this time, but I cannot close without saying what seems to me to be an inevitable conclusion from the premises: With the tremendously complicated background of civilization, with its varied physical, social and spiritual environments, it would seem utterly fool-

ish to expect any program of human breeding directed by a dictator to have any value. Even though we grant that by decree we might breed for superior genes, even though we concede that physical invironment might be improved in such a program, nevertheless is there any possibility that a fine human culture could flower under an authoritarian system? In a high culture a great variety of types and abilities are necessary. We know very little about how such abilities are inherited, or what environment best suits their development. We know that on the mental or spiritual plane, freedom of inquiry and opinion and a definite sense of the dignity of the individual seems to be essential. It is definitely a false eugenic idea to work toward some standardized preconception of the perfect man, such as the "Aryan Race" of the Nazi mythology. No race has a monopoly on desirable genes and there are geniuses in every race. The fact that the dictator type of mind must inevitably over-simplify its problems, and attempt practical solutions, based on such false premises, can only mean that eugenic progress under a dictatorship will fail in the long run. Man does not live by bread alone, nor by genes alone. Without denying the importance of either, the third priceless intangible (hinted at by the founders of our country in such terms as life, liberty, pursuit of happiness, and the right to worship according to the dictates of one's conscience), is just as real a part of the environment of the civilized man as the physical world in which he lives.

To me therefore the democratic ideal, which recognizes the individual as having certain inalienable rights and virtues, seems to offer the only environment to which the type of personality which makes us human beings can flower into maximum development. Only with such a background can we prize genetic and developmental differences which must characterize men and women under a highly specialized civilization. No board of experts can tell a dictator how to breed a genius, nor indicate what kind of children our genius would have—if any. Were this possible we feel sure that a genius-breeding program by decree (even a decree buttressed by 99.75% of the "electorate") could only offer the kind of environment from which the best inheritance would bear only bitter fruit. If the eugenic outlook in democracies is today as bad as some eugenists feel, the solution is thus seen to lie not in an appeal to dictatorship but in the development of a kind of social environment in which superior individuals feel that life has values and possibilities which it is a privilege to pass on tc one's children. This means developing a sense of responsibility and a faith in the future on the part of all our reasonable, capable people. Such an ideal is infinitely more difficult than the false hope of eugenics through dictatorship, but there may be no other solution.

When we consider these few facts bearing on the complicated question of human heredity and environment, it seems clear that the hope of our race lies not in following self-appointed prophets who play on our fears and prejudices but in working toward a culture in which normal people will have the greatest opportunity for developing and leading happy and useful lives. Such a program cannot ignore the knowledge we have gained by genetic research in corn and other organisms. Neither can it go far unless those who undertake to carry it out retain the reality of outlook, and the humility of approach which the plant breeder, if he is to succeed, must have. We cannot legislate new varieties of corn nor a better race of men. We must appeal to nature—and we must apply the best fruits of the human mind and heart if we are to build that better world which is the dream not only of the eugenist, but of all pioneers of the human spirit.

SEXUAL DIMORPHISM IN THE DOWN-COLOR AND ADULT PLUMAGE OF GEESE

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WHITE MALES, GREY FEMALES

Figure 2

Adult male on left and female on right. Of the six partly grown goslings, four are males and two are females (the head of the fourth male is all that is visible). The color difference in the sexes is of considerable practical value, and offers an interesting genetic problem.

IT has long been the desire of poultrymen to discover some practical means of determining sex at hatching time. Various means have been employed with some degree of success. In the case of the chicken, Punnett and Pease[3] succeeded in developing a breed, the Cambar, in which the sexes of the day-old chicks may be separated by differences in the down-color. Warren,[4] working with Single Comb Rhode Island Red chicks, found that down-color is inherited, with 85.3 per cent of the chicks carrying stripes being females. Byerly and Quinn,[1] studying chicks of the same breed as Warren, found that 84.9 per cent of the chicks with stripes or spots of black down on the head were females and 77.8 per cent of the non-spotted, non-striped chicks were males. However, there is still a need for some practical means of distinguishing sex at hatching time among popular breeds of chickens and other domestic birds.

Usually geese have no marked external sex characteristics by which the male and female may be distinguished. Most goose raisers find it necessary to wait until the breeding season in order to be certain how many of each sex they possess, and choose geese for sale in a very haphazard manner instead of being able to select a pair with assurance at any age from day-old to maturity.

DIFFERENCES IN DOWN COLOR

Figure 3

The sex-difference in down color is clearly defined shortly after hatching. The female gosling is on the left in this photograph; the male on the right.

Geese are known to have been domesticated many years before the beginning of the Christian Era. Over 4,000 years ago they were considered sacred birds in Egypt. However, despite their many years of domesticity, the external characters of the goose have been modified very little. Darwin[2] emphasized the fact that hardly any other domesticated birds had varied so little as the goose.

Materials and Observations

In the fall of 1935, several pairs of a variety of goose common in Alabama, were obtained for experimental purposes by the Poultry Department of the Alabama Polytechnic Institute. Upon inquiring of the owner, it was found that the white ones were males and the colored ones females. In view of the fact that such a condition is rather rare among domestic birds, the statement was indeed interesting. The validity of the statement was borne out during the following breeding season.

The males have a solid white plumage except for an occasional grey feather, whereas the females are mostly grey or parti-colored with white areas on the head, breast, and ventral regions. The down-color of the goslings is either light or dark grey. The down-color gradations occur with about equal frequency and of especial interest is the fact that, without exception, the lighter ones develop the white plumage of the male, while the darker ones assume the grey of the female. The eye-color of the two sexes differs markedly in the adult birds; the iris of the male being almost a sky-blue, in contrast to the deep grey or brown of the female. The eye-color difference is not readily distinguishable in the day-old goslings, since both sexes have eyes comparable with those of the adult female.

The size of these geese is somewhat small in comparison with that of most recognized breeds, the mature birds generally weighing between nine and ten pounds. If desired, the size could undoubtedly be increased or deceased within certain limits by selection.

The large size attained by most geese is just as objectionable to the modern housewife with a small family as is too large a turkey. A breed of small geese comparable in size with the smaller bird which turkey breeders are striving for, might aid materially toward increasing the popularity of the goose on the average farm and in the holiday menu.

Discussion

Since most recognized breeds of geese are either grey or white, outcrosses would be desirable in order to determine the relation of the white and grey of the birds herein described, to color existent in established breeds. Some of the females do possess areas of white, especially on the head and breast, but whether these have come about through selection or have been brought out by inbreeding, is problematical. By continued selection it is quite likely that all-white females could be produced, but they are certainly not to be desired if the two sexes are to remain readily distinguishable.

Certain tests must be completed before it can be shown whether the color dimorphism of the goose and gander is

governed by sex hormones or by sex-limited inheritance.

Summary

A variety of goose common on many farms of Alabama has been described, wherein the male plumage is entirely white except for an occasional grey feather, whereas the females are grey or parti-colored with certain individuals having areas of white on head, breast, and ventral regions. Without exception, the geese have bred true for the color dimorphism.

It is posible to identify the sexes at hatching time, inasmuch as the males have light and the females dark grey down.

The iris of the adult male eye is sky-blue and that of the female dark grey or brown. The eye-color contrast is not apparent in the young goslings.

The rôle played by inheritance and sex hormones in the determination of the adult plumage dimorphism has not been ascertained.

The significance of such a variety of goose is apparent when its size and ease of separation of the sexes are fully considered in the light of present day trends.

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Cytology From Fruits to Nuts

THE determination of the genetic and chromosomal constitution of plants is now universally regarded as a study of practical value to plant breeders. Dr. B. R. Nebel, Associate in Research (Pomology) at the Geneva, N. Y., Experimental Station, is the author of a booklet* on the cytology and genetics of some cultivated plants. Primarily for plant breeders, it is the first book on this subject to be written in the German language.

In Part I, the fundamental principles of cytogenetics are described, and the more important lines of reseacrh indicated. Two methods are considered practical: first, the study of mutations; second, the production of fertile tetraploids from sterile hybrids by doubling the chromosome number. Although the elementary concepts of cell mechanics are explained quite clearly, the author has included a diagram of a chromosome in which four spirals are shown. Since this phase of chromosome structure is still in a controversial stage, this interpretation is more apt to confuse than clarify the explanation of mitosis and meiosis for the audience for whom the discussion is intended.

Part II is an account of cytogenetic researches in various groups of fruits and nuts, especially those grown in the North Temperate regions. Under each group, information has been brought together on chromosome numbers, the methods of inheritance of characters so far discovered by various workers, and theories concerning the origin of the following fruits and nuts: Apples, Pears, Plums, Cherries, Peaches, Apricots,

*Nebel, B. R. Zellforschung und Neuzuchtung beim Obst und bei der Rebe. 58pp. RM. 1.65. Grundlagen und Fortschritte im Garten und Weinbau. Heft 29. Eugen Ulmer, Stuttgart-s, Olgastr. 83 (Germany). 1936.

Walnuts, Chestnuts, Hazelnuts, Strawberries, Raspberries, Blackberries, Blueberries, Gooseberries, and Grapes. In a brief glossary, 31 genetic terms are defined.

Although this booklet is intended as an aid to practical breeders it may be too technical to be of great value to those not familiar with the specialized techniques by which plants are examined for cytogenetic purposes. On the other hand, specialists engaged in breeding work with the various fruits and nuts, will certainly appreciate the information that has been assembled in Part II.

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The Seventh International Botanical Congress

Stockholm, 17—ca. 25 July 1940

SOON after the Sixth International Botanical Congress (Amsterdam, 1935) had decided to accept the invitation for the next Congress to be held in Stockholm in 1940, the preparatory work for the Seventh Congress was begun. An Organizing Committee and an Executive Committee were formed, both of which are under the guidance of Professor Rob. E. Fries. Preliminary notices about the Congress have already been published in *Chronica Botanica* (Leiden, The Netherlands, 1937 and 1938).

The Congress will be divided into eleven sections:

AGRONOMY (Recorder: Prof. H. Osvald, Lantbrukshögskolan, Uppsala).
CYTOLOGY (Recorder: Dr. O. Heilborn, Germaniavägen 6, Djursholm).
EXPERIMENTAL ECOLOGY (Recorder: Prof. G. Turesson, Lantbrukshögskolan, Uppsala).
GENETICS (Recorder: Prof. A. Müntzing, Svalöv).
MORPHOLOGY and ANATOMY (Recorder: Prof. H. Kylin, Botaniska Institutionen, Lund).
MYCOLOGY and BACTERIOLOGY (Recorder: Prof. E. Melin, Botaniska Institutionen, Uppsala).
PALAEOBOTANY (Recorder: Prof. T. G. Halle, Riksmuseum, Stockhlom 50).
PHYTOGEOGRAPHY (incl. Comparative Ecology) (Recorder: Prof. G. E. Du Rietz, Växtbiologiska Institutionen, Uppsala).
PHYTOPATHOLOGY (Recorder: Prof. T. Lagerberg, Skogshögskolan, Experimental-(ältet).
PLANT PHYSIOLOGY (Recorder: Prof. H. Lundegårdh, Lantbrukshögskolan, Uppsala).
TAXONOMY and NOMENCLATURE (Recorder: Dr. J. A. Nannfeldt, Botaniska Institutionen, Uppsala).

For some of these sections also joint meetings are planned to a certain extent.

Besides several botanical institutions in and near Stockholm the Congress will visit the botanical institutions of the University and the Swedish College of Agriculture at Uppsala. This part of the programme will also include a visit to Hammarby — the country house of Carolus Linnaeus — the Hortus Linnaeanus etc. Furthermore, visits will be paid to Lund (Botanical Institute) and Göteborg (Gothenburg Botanical Garden).

In addition the following excursions are planned:

Phytogeographical excursion (2 weeks) to South Sweden, before the Congress;
Excursion to Lund, Svalöv, and Landskrona in South Sweden (1-3 days), before the Congress, for the purpose of visiting certain plant-breeding stations;
Phytogeographical and floristic excursion into the Stockholm Archipelago (1 day), during the Congress week;
Mycological excursion to Femsjö in Småland (1 week), the collecting ground of Elias Fries, after the Congress;
Phytogeographical excursion (3-4 weeks) through North Sweden, after the Congress;
Floristic excursion (1 week) to Abisko in North Lapland, after the Congress.

Further notices about the Congress will be sent at about the beginning of 1939.—DR. C. R. FLORIN, *Secretary*, Riksmuseum, Stockholm 50, Sweden.

"LAZINESS" IN MAIZE DUE TO ABNORMAL DISTRIBUTION OF GROWTH HORMONE

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MANY varieties of maize are of interest to the physiologist because the study of them offers an opportunity to learn something of the processes which link the gene with the final appearance of the plant. With this in mind several genetic dwarfs have been studied, and it was found that their dwarfed appearance was correlated with a lack of auxin, a growth hormone controlling the growth of plants.[4, 8] Dwarfness in *Pisum*[1] and *Epilobium*[2] has also been linked with the lack of auxin. For *nana*, one of the dwarf varieties of corn,[4, 8] and for a short variety of *Pisum*[1] the physiological causes of dwarfism have been traced back one step further. It has been shown in these cases that the lack of auxin is due to an excessive destruction of this hormone. Furthermore, there is evidence to believe that this destruction is an oxidation process.[1, 4, 6]

Another interesting variety of corn is "lazy," a variety which has a prostrate habit of growth. In an earlier article in this JOURNAL[5] it has been shown that the "laziness" of this variety is due to an indifference to gravity rather than to a structural weakness of the stem. Since the response of plants to gravity has been proven to be due to a differential distribution of auxin the question arose whether the inability of the *lazy* plant to respond to gravity could be linked with some abnormality in the distribution of auxin in the stem. This, indeed, was found. Shafer[3] attacked this problem in the following way. He cut sections from stems of semi-mature *lazy* plants and of comparable controls. The sections were placed horizontally and a certain dosage of auxin was applied to the morphological apex. The auxin was collected in two agar blocks covering respectively the upper and the lower half of the basal cut surface of the sections. It was found that if sections of standard ("normal") corn plants were used more auxin was found in the lower block than in the upper. This was expected because many investigators have found that from the lower half of coleoptiles and hypocotyls more auxin can be obtained by diffusion than from the upper half, when placed horizontally. The sections of the *lazy* plants on the contrary, showed more auxin in the upper block than in the lower. Thus it appeared that the differential distribution of auxin which normally takes place when stems are put on their side, does not take place in *lazy* stems and may even be reversed. Due to the high rate of auxin destruction in maize sections only a small percentage of the auxin applied at the apical cut surface is recovered at the base of the sections. This makes the results rather uncertain and it appeared desirable to see whether this abnormal distribution of auxin in the *lazy* stems normally (without auxin application) existed in this plant. Theoretically the simplest way to determine the auxin distribution is to extract it from the upper and lower part of the horizontal stem. But only recently has an auxin extraction technique been worked out which gives satisfactory results with maize.[7] By means of this method the auxin distribution of *lazy* plants has been studied.

Experiments

The seeds like those used in previous experiments originated from stocks kept by Dr. E. G. Anderson. A backcross of homogeneous *la* with F_1 provided seed material from which segregated 50%

lazy and 50% standard plants. The plants were grown in pots in the greenhouse during the early months of 1938. At a stage of development when the pollen was about to shed, the standard plants were put on their sides and kept there for one or more days by placing empty flowerpots on the stems. After this period of time the leaf blades were removed and the stems of *lazy* plants and controls were carefully split into an upper and a lower half. The nodes plus about ¼ inch of the stem on both sides were analyzed separately from the internodes. The material was weighed, the auxin extracted and its concentration determined in a way described previously.[7] In general three *lazy* plants and three standard plants were used for each experiment. The nodal region and the internodes were analyzed separately because when a normal corn plant is put on its side it will right itself after some time due to differential growth in the nodal region of the stem.[3] Thus differences in auxin distribution found in the nodal region are of more importance than those found in the internodes.

Table 1 shows the auxin concentration and the relative auxin distribution in stems of *lazy* and standard corn. In the nodes of *lazy* the auxin concentration was constantly higher than in the standard plants. This may account for Shafer's observation that the nodes of *lazy* grow longer than those of standard plants. The auxin content of the internodes appeared to be the same in the *lazy* and the standard corn plants. The relative distribution of auxin in the nodes of horizontal stems of standard corn is also shown in Table I. On the average the lower half contains more auxin than the upper half. It was found that if plants were kept horizontally for 10 days or longer the results were less clear cut than if the stems were kept horizontally for only a few days. Also the internodes of horizontal stems of standard plants appear to have on the average more auxin in the lower half than in the upper.

Stems of *lazy* corn, which are naturally horizontal, were found to have on the average more auxin in the upper part than in the lower part of both nodes and internodes. This agrees with Shafer's findings that more auxin diffused out of the upper half than out of the lower half of horizontal sections of stems of *lazy* corn, when auxin was applied to the morphological apex.

The fact that somewhat more auxin is found in the upper than in the lower half of the *lazy* stems should lead to a positively geotropic bending of the stem provided that the sensitivity to auxin is the same in both parts of the stem. Now it appears that if a number of *lazy* plants are examined three types can be distinguished. (1) *Lazy* plants which are lying flat but whose tips are more or less curved up. Such plants seem to be somewhat negatively geotropic and were mostly discarded as experimental material. (2) *Lazy* plants which are lying flat and are entirely straight. Such plants seem to be entirely a-geotropic. (3) *Lazy* plants which are more or less curved downward and hence appear to

TABLE I. Auxin concentration (gamma indole-acetic-acid-equivalents per kg fresh weight) and relative auxin distribution in the upper and lower halves of horizontal stems of lazy and standard maize.

Experiment number	Time in horizontal position in days	Standard Plants						Lazy Plants					
		nodal region			internode			nodal region			internode		
		auxin concentration	relative distribution		auxin concentration	relative distribution		auxin concentration	relative distribution		auxin concentration	relative distribution	
			upper half	lower half		upper half	lower half		upper half	lower half		upper half	lower half
80308	8½	.305	100	144	.240	100	127	.448	100	78	.370	100	90
80310	8	.265	100	116	.176	100	134	.371	100	89	.350	100	91
80312								.358	100	67	.185	100	66
80717	18	.129	100	130	.047	100	108	.173	100	96	.204	100	98
80398	10	.151	100	180	.017	100	150	.219	100	68	.407	100	74
80331	10	.183	100	105	.079	100	89	.467	100	106	.550	100	93
80420	12	.850	100	94	.365	100	98	.265	100	109	.264	100	114
Average		.197	100	121	.071	100	107	.322	100	90	.350	100	87
		±.054			± .029			±.049			±.058		

TABLE II. Auxin distribution in stems of *lazy* plants which have been turned 180° around their longitudinal axis 10 days before the auxin analysis was made. (80328)

	Auxin concentration (gamma indole-acetic-acid-equivalents per kg fresh weight)	Relative distribution
Nodal region		
Upper half	.325	100
Lower half	.271	83
Internode		
Upper half	.251	100
Lower half	.274	109

be slightly positively geotropic. Plants which showed a pronounced "laziness" were used in the experiments described above, such plants belonged to the groups (2) and (3). In order to find out whether the downward bending of some of the *lazy* plants indeed takes place in response to gravity, the following experiment was performed. Three *lazy* plants with a markedly downward-bent stem were selected and turned along their longitudinal axis for 180°. Thus their stems became bent upward. After about 10 days the stems had become bent downward again. When these *lazy* stems were analyzed their nodes at least showed a higher auxin concentration in the upper half than in the lower half, strongly indicating that this type of *lazy* plant may respond to gravity, but that the resulting auxin distribution is the reverse of that found in standard corn plants (Table II).

Conclusions

The auxin concentration in horizontal stems of *lazy* and standard corn has been determined by means of extraction with ether. In the stems of the standard plants more auxin was found in the lower half than in the upper. In the *lazy* stems on the other hand, somewhat more auxin was found in the upper half than in the lower. This provides a logical explanation for the prostrate habit of growth of the *lazy* plants. It is thus evident that the lazy gene interferes with the auxin distribution in the stems which normally takes place under the influence of gravity.

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HEREDITARY SUSCEPTIBILITY TO SEPSIS

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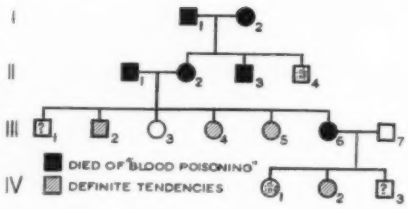
GENERAL infections are popularly known by the term "blood poisoning." This condition is caused by the invasion into the blood stream of bacteria or their toxins. These general infections are usually classified into toxemia, septicemia, and pyemia. In toxemia the bacteria are localized and pour their toxins into the blood. Septicemia is characterized by the fact that bacteria are found in the blood stream. Pyemia is brought about by the passage from the infected area to the blood of clots which might be infected with pyogenic bacteria or saturated with toxins of these bacteria. It is the thesis of the present article to inquire into the possibility of inheriting susceptibility to these infections.

This year a genetic student in one of the author's classes called attention to the fact that many of her ancestors died of "blood poisoning." An investigation was started revealing the facts shown in Figure 4.

The illustration shows it is undoubtedly a reality that in this strain a hereditary susceptibility to general infection or "blood poisoning" exists. By a study of the chart it can be seen that of sixteen individuals, covering four generations, six died of "blood poisoning" and four living persons have definite tendencies. By definite tendencies is meant easy infection of the individual. Of the remaining six individuals two died in early infancy (II-4 and IV-1), and no information can be secured per-

taining to two others (III-1 and IV-3). Two persons do not have any definite tendencies.

The present study indicates this susceptibility is probably inherited as a dominant autosomal factor. This conclusion is illustrated in the third generation. The ancestors of III-7 show no tendencies toward "blood poisoning." In the marriage of this man to a woman (III-6) who died of general infection the trait is passed on to their descendants. Of the three children resulting from the marriage one died in infancy, one has definite tendencies, and of the other we have no information.



FOUR GENERATIONS OF SUSCEPTIBILITY TO SEPSIS

Figure 4

Pedigree chart showing hereditary susceptibility to sepsis. In this study the tendency appears to be inherited as a dominant autosomal factor.

The fact of susceptibility to disease is known in numerous instances. It is agreed that various cells of the human body have affinity for particular toxins. Tetanotoxin has affinity for the nervous system and typhoid toxin for endothelial cells. Such affinity shows the possibility of the body cells having susceptibility to toxins that produce "blood poisoning."

In a study of the literature we find many references to the hereditary susceptibility to disease. Hogben[4] informs us that "whatever else it may accomplish, genetic science can teach us much about the factors which determine susceptibility to disease for which curative measures are not yet available." We also read from Otto L. Mohr:[5] "As regards the question of hereditary immunity, or resistance to particular diseases, a varied body of evidence both from plants and animals indicates that such an immunity may be distinctly hereditary."

The author does not intend this study to intimate that susceptibility to "blood poisoning" is always inherited. In Sajous' *Analytic Cyclopedia of Practical Medicine* we find this statement: "The prognosis in all forms of sepsis depends greatly upon the powers of resistance of the patient."[6] This resistance may result from environmental influences, or depend on the genetic constitution, or both. We cannot ignore the salient fact that nurture may lower or influence body resistance to infection: as a consequence, environment and heredity may give results that are similar. Nevertheless in mammals the case for inherited differences in susceptibility to pathogens is so strong as to lead Gowen[3] to summarize the matter in these striking words: "No investigator who has adequately sought inherited host differences to disease response has failed to find them."

While investigators are virtually unanimous that man is among the worst of organisms for "genetic experimentation" that exists, much has been learned by compiling what data chance brings to hand. The fragment here recorded seems to suggest that in some instances, heredity plays the paramount rôle in susceptibility to sepsis.

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COMPARATIVE STUDIES ON THE CHROMOSOME NUMBERS IN SHEEP, GOAT, AND SHEEP-GOAT HYBRIDS*

R. O. BERRY†

IN the study of mammalian cytology, one is confronted with the task of dealing with a large number of chromosomes in a relatively small cell. This condition has hindered materially the obtaining of much detailed information concerning the structure and form of the chromosomes in this group of animals. But in spite of these difficulties, much has been learned about the general morphological features and behavior of the chromosomes in a number of the common mammals. The evidence indicates that the chromosome constitution of mammals varies rather widely even within apparently closely related species. However, these differences may not be as numerous as they first appear since there is a tendency to stress observed differences and to minimize the similarities when making comparisons. From a phylogenetic standpoint, closely related animals would be expected to have a similar chromosome constitution, and the more diverse forms a less similar chromosome constitution. This is generally true for most of the animals, but there are cases which do not follow this rule. The most widely offered explanation for these diversities is that they have arisen through structural changes, such as translocation, inversion, deletions, and deficiencies within the various chromosomes. Such changes, however, may or may not occur in closely related species with the same frequency. Thus one species may prove to be highly stable while in another, modifications may occur more readily. Such being the case chromosome morphology and chromosome numbers may take a different aspect even in closely related groups.

Literature

Cross[2] found in rodents a chromosome variation in diploid number of 48-52 in four different species of the genus Peromyscus, and from 48-62 in three species of the genus Sciurus. The chromosome variation for the rodents was given by him as ranging from 40 to 86.

Painter[7] described a morphological, as well as a numerical, difference between the chromosome complex of the common house mouse (*Mus musculus*) and the white rat (*Mus norvegicus*—later called *Rattus norvegicus*). *Rattus norvegicus* had a diploid number of 42 chromosomes with two pairs being much larger than any of the others and *Mus musculus* had 40 chromosomes without much variation in size.

Pincus[8] made a study of two species of rats which would not hybridize and found the chromosome numbers to be 42 in the Norway rat (*R. norvegicus*) and 40 in the black rat (*R. rattus*). Also a morphological comparison of the first spermatocyte tetrads in the two species showed the presence of a large K-shaped chromosome in *R. norvegicus* which was not present in *R. rattus*.

The earliest work on the chromosome numbers in the sheep was reported in 1922 by Wodsedalek.[13] He stated that 33 chromosomes occur in the spermato-

*Report of part of a cooperative project of the Agricultural Experiment Station, Biology Department of the School of Arts and Science, and Genetics Department of the School of Agriculture, Agricultural and Mechanical College of Texas, College Station, Texas.

The author wishes to express his appreciation to Dr. B. L. Warwick of the Texas Agricultural Experiment Station for making the necessary matings and assisting in obtaining the material on which this study is based, also to Dr. C. W. Metz† and to Dr. R. G. Reeves of the Agricultural and Mechanical College of Texas, for many helpful suggestions and criticisms.

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gonia and that 17 appear in the spermatocyte division. Sixteen of the latter are bivalent while the other is a large unpaired sex chromosome. Thirty-four chromosomes were given as the diploid number for the oögonia. He also stated that the prevailing number of chromosomes in the somatic cells of the male and female embryos correspond respectively to the number in the germ cells.

Krallinger[3] reported the chromosome number in the spermatogonial cells of the sheep as 50-60 with 60 being the most probable number. He counted 30 chromosomes going to each pole at the anaphase of the first meiotic division and believed that the sex chromosome mechanism was *X* and *Y*. Some of the chromosomes were *V*-shaped. He also reported in the goat 60 chromosomes as the diploid number with 30 chromosomes in the primary spermatocytes. He did not observe the *V*-shaped chromosomes in the goat.

A very comprehensive work on the spermatogenesis of the goat was done by Sokolov.[10] He found conclusive evidence for the *X* and *Y* sex chromosome mechanism. The *X* was observed as a straight or bent rod-shaped chromosome, and the *Y* as a small spheroidal one. He concluded that the sex chromosomes persist through interkinesis in a heteropycnotic condition and thereby two types of spermatocytes are formed, one with a large heteropycnotic body and one with a small one. Sixty chromosomes were found in the spermatogonial metaphase and 30 in the metaphase of the second meiotic division. In the spermatogonial metaphase the longest chromosomes were 3-4 times the length of the shortest ones.

Shiwago,[9] in his studies on the diploid number of chromosomes in the amnion of the goat and of the sheep, observed 60 chromosomes in the goat and 54 in the sheep. In the latter, chromosome numbers as low as 48 were counted. Those, however, were exceptional cases.

Material and Methods

Interest in the chromosome complex of the sheep and the goat was stimulated by the results of matings made between goats and sheep by Warwick, Berry, and Horlacher.[11, 12] A series of these matings was made at the Texas Agricultural Experiment Station between Angora female goats and Merino rams. In about 45 per cent of these matings the females became pregnant but aborted before the time for normal parturition. Degenerate aborted embryos and fetuses were recovered as late as 145 days after mating. In addition five living embryos, ranging in ages from 30 days to 65 days, were taken from the uteruses of sacrificed mothers. In attempting to explain the above results from a cytological point of view, one is faced with questions as to the similarity or dissimilarity of the chromosome complex of the two species. A study has been made in an effort to clarify the reason or reasons for the failure of the embryos to survive. This work has been limited chiefly to a study of the chromosomes in the amniotic tissue, largely because comparable testicular material could not be obtained from the hybrid. The amnions from 30-day embryos of one domestic goat (*Capra hircus*), three domestic sheep (*Ovis aries*), and two goat × sheep hybrids furnished the material for the study. In each case the entire uterus with the embryo intact was removed from the living mother. This embryo with its surrounding amniotic membrane was immediately dissected out and placed directly into a solution of Allen's B-15 at body temperature, and a quantity of the fixing fluid sufficient to replace the amniotic fluid was injected into the amniotic cavity by means of a hypodermic syringe. Painter's[6] method of fixation and staining was used. The large size of the amniotic cells and the facility with which this tissue can be prepared makes it favorable for chromosome studies. This, however, is partially offset by the difficulty in obtaining the materials. The amnion from 30-day embryos proved to be better than that from 45-day embryos which were also tried, because, in the latter, the allantoic membrane was partially fused with the amnion.

All of the drawings were made at

table level with the aid of a camera lucida, a Bauch and Lomb 1.30 apochromatic oil immersion objective, and a 30 × compensating ocular. The photographs were made with the 1.30 apochromatic oil immersion objective and a 15 × ocular.

Observations

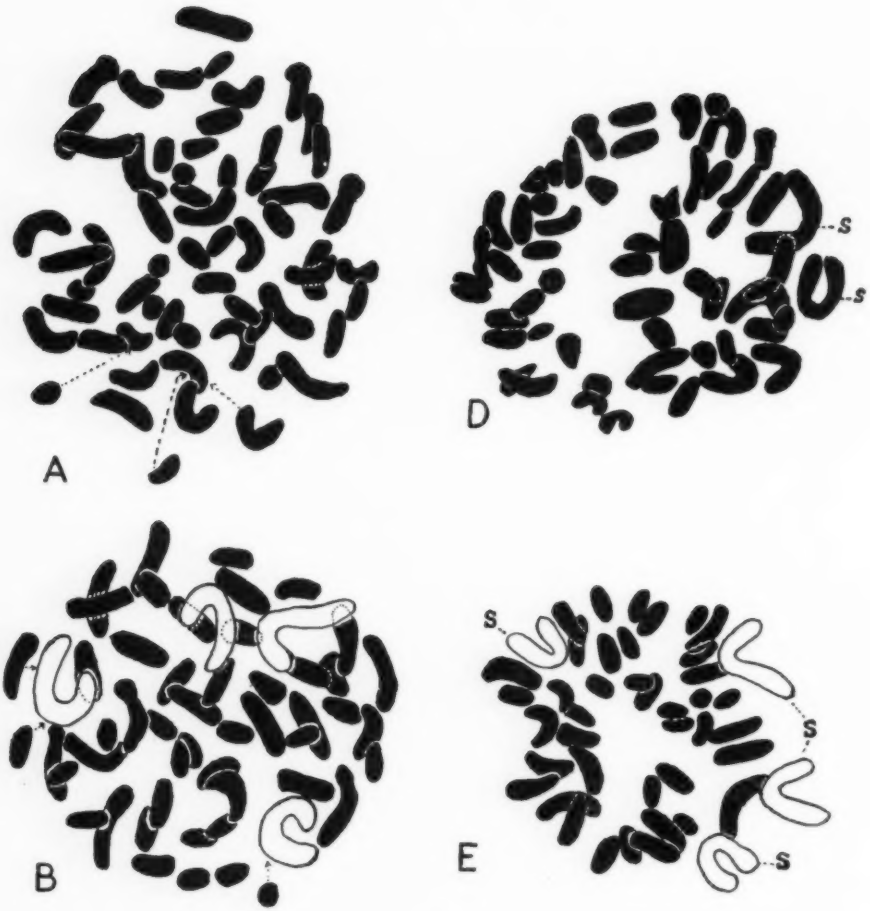
In the amniotic material from the goat, excellent figures were found in which 60 chromosomes were counted. They were in the form of long rods, short rods, bent rods, and spheres (Figure 5*A*). Their shape and size was of such nature as to permit easy counting. In the early prophase the rods sometimes assumed a *J*- or *U*-shaped form; but at the metaphase they took the form of long or short rods radiating out from a central axis. This attenuated arrangement was observed by Sokolov in the metaphase of the spermatogonial cells.

The chromosome number found in the amnion of the sheep agrees very closely with the number given by Shiwago.[9] Also the figures shown by him are quite similar to those found in this material. The number of chromosomes observed in most of the cells was 54 (Figure 5*B*). In the cells where counts other than 54 were made, only in rare instances did they exceed 54, and in such cases by not more than two. In a few cells the number observed was 44. The most noticeable characteristic of the chromosome complex of the sheep was the rather constant *J*- or *U*-shaped condition of the four largest chromosomes. This shape was frequently observed in the prophase and was maintained in the metaphase. In a polar view of the metaphase plate, these chromosomes can be seen lying near the periphery of the cell with both arms pointing outward from the center of the nucleus as indicated by the letter *S* in Figures 5 and 6. The size difference and the morphological characteristics make possible the identification of homologues in the case of the four largest chromosomes.

Fifty-seven chromosomes were counted in most of the cells of the hybrid. These probably represent 30 goat chromosomes and 27 sheep chromosomes. The similarity in the size of most of the chromosomes in the two groups makes it impossible to distinguish one group entirely from another. However, since two of the chromosomes contributed by the sheep have a characteristic shape and are larger than any of those of the goat, they can be definitely identified (Figure 5*C* and *D*). They maintain their *J*- or *U*-shape and lie near the periphery of the cell in the metaphase stage (Figure 5*B*, *C*, and *D*). They maintain their individuality unmodified by the introduction of the new chromosome complex. The mitotic figures appear normal and uniform throughout and their number is as frequent as those in the amnion of either the goat or the sheep.

Discussion

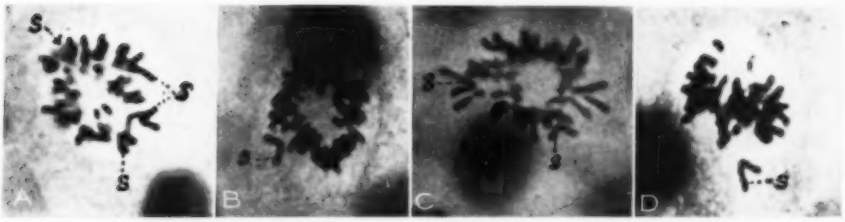
It is natural to expect that each cell of the animal body would contain the same number of chromosomes unless some factor intervened to prevent their equal distribution to daughter cells. A number of workers have reported chromosome variations in the somatic cells of various vertebrates. Some of these variations are probably caused by the techniques used, but such reports are far too numerous for all of them to be attributed to this particular cause. Andres and Jiv[1] have reviewed the literature of the work done on the somatic chromosomes of a number of animals; thus a repetition of their review will not be included here. Their work on various types of somatic cells from normal human embryos revealed cells with a variation of from 32 to 73 chromosomes. Such extreme variations, however, were not numerous, for the number of chromosomes counted in most of the cells was approximately the diploid number 48. The variations were not confined to any particular type of tissue, as each type studied showed some degree of variation but the limits of variation were less in the amnion than in any other tissues (37-54). Andres and Jiv considered the non-disjunction of one or several pairs of chromosomes as the chief cause of these variations and as-



CHROMOSOMES OF SHEEP, GOAT, AND A SHEEP × GOAT HYBRID

Figure 5

A—Late prophase from the amnion of a goat embryo showing 60 chromosomes. *B*—Late prophase from the amnion of a sheep embryo with 54 chromosomes. *C*—Late prophase from the amnion of a goat × sheep hybrid, 57 chromosomes. The two largest chromosomes (*S*) can be identified as being from the sheep. *D*—Metaphase from the amnion of a goat × sheep hybrid, 56 chromosomes. The two largest chromosomes (*S*) are sheep chromosomes. *E*—Metaphase from the amnion of a sheep embryo. The four largest chromosomes are in their typical position for the late metaphase stage. Same cell photographed in Figure 6, *A*. For the sake of clearness, some of the chromosomes were moved from their positions as indicated by the arrows.



PHOTOMICROGRAPHS OF SHEEP-GOAT CHROMOSOMES

Figure 6

A—Metaphase from the amnion of a sheep embryo. A camera lucida drawing of this cell is shown in Figure 5 *E*. *B*, *C*, and *D* are metaphase stages from the amnion of a goat × sheep hybrid showing the largest sheep chromosomes. These are marked S.

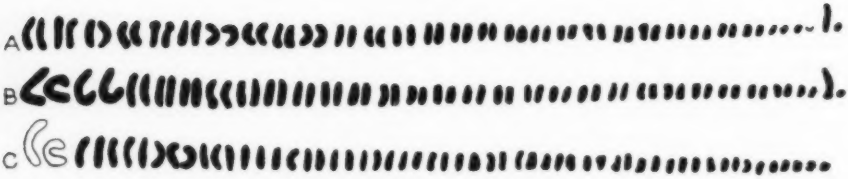
signed an insignificant role to other possible causes such as fragmentation, association and elimination, and multipolar mitosis.

In sectioned material there is always the possibility of some variation due to the sectioning process itself. But the whole mounts of the amnion, such as were used in this study, eliminate the possibility of variation from such a cause. Nevertheless variations were in evidence in the amniotic materials studied. These were less frequently observed in the cells from the goat than in cells from the sheep or from the hybrid. In cells of all three or these animals variations occurred in tissue that was almost, if not entirely, free from mitotic abberations. Lagging or non-disjunction of chromosomes was not observed in any of the cells. Since Andres and Jiv gave non-disjunction as the foremost cause of variations in the amnion of the human embryo, this feature was given special attention; but even in the hybrid cells where it might be expected to occur, it was not observed. The only irregularities encountered were two cells in the hybrid in which there was tripolar mitosis.

Since more than two chromosomes above the diploid number for the species were never found, and since sometimes as many as ten below were found, and since instances of this hyperdiploid condition were very rare as compared to the subdiploid condition, it seems evident that the influences causing the variations produce, for the most part, a diminishing effect. A number of mitotic irregularities which have a tendency to increase the chromosome number in certain cells and at the same time an equal tendency toward decreasing them in others are known. Foremost among these is non-disjunction or non-separation of the split halves of one or more chromosomes. By this process one daughter cell receives one or more extra chromosomes and the other decreases by an equal number. Furthermore in cells where non-disjunctions occur, lagging is frequently observed. But since no high chromosome numbers were encountered, and since lagging of chromosomes was not observed, non-disjunction is evidently not the cause of the variations.

Another possible cause of variations is multipolar mitotic figures. In spite of the fact that multipolar mitosis was rarely observed, it may account for more variations than is at first apparent. For a single case of multiplar mitosis in the early stages of development could give rise to a large number of cells in the succeeding division with diverse chromosome numbers, if they continued to divide normally in the subsequent stages.

Somatic pairing, fusion, and the elimination of one or more chromosomes have a reducing effect upon the chromosome number. In some animals, pairing of the somatic chromosomes occurs (Metz[4]), thus the chromosomes have the appearance of a haploid number. But pairing of the entire complex does not occur in the chromosomes of the amniotic cells, as is



CHROMOSOMES COMPARED

Figure 7

Serial alignment of the chromosomes from the amnion cells of (*A*) goat, (*B*) sheep, and (*C*) goat × sheep hybrid. These were made from cells in Figures 5 *A*, *B*, and *C* respectively.

indicated by the fact that the chromosome number was never far below the diploid number. Complete pairing would give the haploid number.

Although the end-to-end fusion of some of the chromosomes would give results in chromosome numbers comparable to those observed, such a process of fusion of whole chromosomes in living cells is not known to occur, and there is nothing to indicate that such is the case here. Furthermore, since no indication of the elimination of chromatin material was found, it, too, is probably not a cause for the reduced chromosome number.

Another influence which may have an apparent reducing effect is the fixation process. In poorly fixed tissues such a reduction manifests itself in the clumping or fusion of the chromosomes. Since all fixations produce changes in the protoplasm to a certain degree, there is a question as to whether, in cells where there is a large number of chromosomes, the smaller chromosomes do not frequently fuse or stick to other closely adjacent ones in many of the cells even when fixation is considered good.

Figure 7 shows a serial alignment of the chromosomes from cells of comparable stages of the goat, sheep, and hybrid. It is evident that the cell from the sheep contains some chromosomes that are larger than those of the goat, and morphologically different. This difference is sufficiently great to allow at least two of the sheep chromosomes to be identified in the cells from the hybrid. These two chromosomes not only maintain their morphological characteristics in the hybrid, but are frequently found in the metaphase stage lying close to the periphery as was characteristic of their behavior in the sheep cells. The identification of these two chromosomes in no way precludes the possibility that the other chromosomes have distinguishing characters by which they could be identified, but at present such characters have not been observed.

Since the time when the ancestral sheep and the ancestral goat probably took their origins from their common ancestor, changes have occurred in their chromosome complex which have resulted in a difference in chromosome numbers. This difference may be accounted for in either of two ways, depending upon which species is assumed to be more nearly like the common ancestor. For instance if the 54 chromosomes found in the sheep are assumed to be the stem number, the increase to 60 for the goat may have been caused by fragmentation, with this fragmentation occuring especially among the larger chromosomes. On the other hand if the goat is assumed to have more nearly the stem number, the decrease to 54 may have been caused by end-to-end fusion of some of the chromosomes. If the typical chromosome number for Eutheria is about 48, as given by Painter,[5] it seems more likely that fragmentation is the logical explanation for the difference. It would not be necessary to assume any other changes in order to harmonize the chromosome complex of the two species, since the one with the lowest chromosome number also possesses the largest chromosomes. But one of the essential

requirements for the perpetuation of the fragments of a chromosome is that it possess a spindle fiber attachment. Since in the sheep some of the largest chromosomes have a subterminal spindle fiber attachment, it might be postulated that these large chromosomes could become rod-like telomitic chromosomes by the occurrence of a fragmentation in such a way as to give both arms of the fragmented chromosome a part of the insertion attachment. However, there is no direct evidence for such a hypothesis, and the methods by which chromosome numbers have become changed in the evolutionary process are at present a matter of conjecture.

Notwithstanding the difference in chromosome number and morphology, the sperm of the sheep will fertilize the ovum from the goat, and the nuclei from the two will fuse and stimulate the development of an embryo to approximately two-fifths of its gestation period. This development is not initiated merely by the entrance of the sperm into the egg without its making any further contribution to the role of development. But the chromosome complex contributed by the sperm joins that of the egg and both are retained in subsequent development.

If similarity in chromosome complex is to be considered as one of the bases for judging animal relations, and thereby as an indication of their ability to hybridize, it seems that the chromosome complex of the domestic goat differs sufficiently from that of the domestic sheep to prevent the complete development of a normal hybrid from the two species. The fact that the hybrid develops normally for a period seems to indicate that the genetic constitution of the two species is quite similar; at least much more so than the chromosome condition would indicate. The arrangement of the gene complex in the two species with different chromosome numbers would necessitate a difference in the grouping of the genes on the various chromosomes, assuming that some of the chromosomes were not "empty." It is problematical just what the effect on development would be with cells having two sets of chromosomes on which the genes are not similarly aligned, but that within itself is probably not the cause which would arrest development. However, it is quite likely that mutations, owing either to this change in their position in the chromosomes or to other causes, have occurred in one species and not in the other, thus producing such a genetic constitution that if the genes of the two species are combined, as they are in the hybrid, their united effects are sufficiently out of harmony to cause the death of the embryo. It is possible that recessive lethals, which are masked in a diploid complement, would be left "uncovered" by normal allels in the hybrid.

Summary and Conclusions

1. This study was confined to cells from the amnion of 30-day embryos of the goat, the sheep, and the goat × sheep hybrid. The number of chromosomes counted was 60, 54, and 57 for the three groups respectively.

2. The four largest chromosomes of the sheep are larger than any of those of the goat, and assume a characteristic *J*- or *U*-shape in the metaphase plate.

3. The cells from the hybrid had a full diploid number and the two largest chromosomes, contributed by the sheep parent, could be definitely identified.

4. Variations in the chromosome numbers within the cells of an individual species were observed. The reason for this variation was not apparent.

5. Hypothetically, the chromosome complex of the sheep could be made to resemble that of the goat by a fragmentation of the former.

6. The chromosome complex of the sheep differs from that of the goat to such an extent that a hybrid from the two species concerned would likely have a dissimilar genetic constitution. This probably accounts, in part at least, for the early fetal death *in utero*.

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Inca Bulldogs

Hilzheimer, M. und R. N. Wegner. *Die Chicha-Bulldoge.* Eine ausgestorbene Hunderasse aus dem alten Peru. 43p. 16 figs. Verlag Dr. Paul Schöps, Leipzig, 1937.

This is a report concerning a breed of dogs which existed at the time of the Incas of Peru. The authors studied skeletal remains and ceramic reproductions. In many features this extinct breed apparently showed close resemblance to the modern French Dwarf Bulldog, but there are also definite differences, especially with regard to the conformation of the skull. Many of the ceramic reproductions show individuals with cleft upper lip, a trait which at one time was common also among bulldogs. There are excellent illustrations.

W. Landauer.

✦

Genetics of Flax and Hemp

GENETICS AND SELECTION OF HEMP ("GENETIKA i SELEKTZIA KONOPLI"). Report of the Hemp Institute, edited by N. N. Grischko, P. F. Panchenko, and K. V. Maluscha. Published by Lenin's Academy of Agr'l Sciences-Moscow-Leningrad. Pp. 286, many illustrations and diagrams. 1937.

A symposium by numerous authors, on genetics and breeding of flax and hemp. Cytological studies on the hemp plant are presented and a discussion of sex determination in hemp. Anatomical peculiarities of different varieties are set forth and practical breeding programs for both are discussed. The book closes with a translation of an article on hemp breeding by Dr. L. P. Dewey of the U. S. Department of Agriculture. A bibliography in Russian concludes each of the fifteen chapters.—J. W. PINCUS

PROPHASE CHROMOSOME BEHAVIOR IN THE DIVISION OF CELLS WITH MULTIPLE CHROMOSOME COMPLEXES

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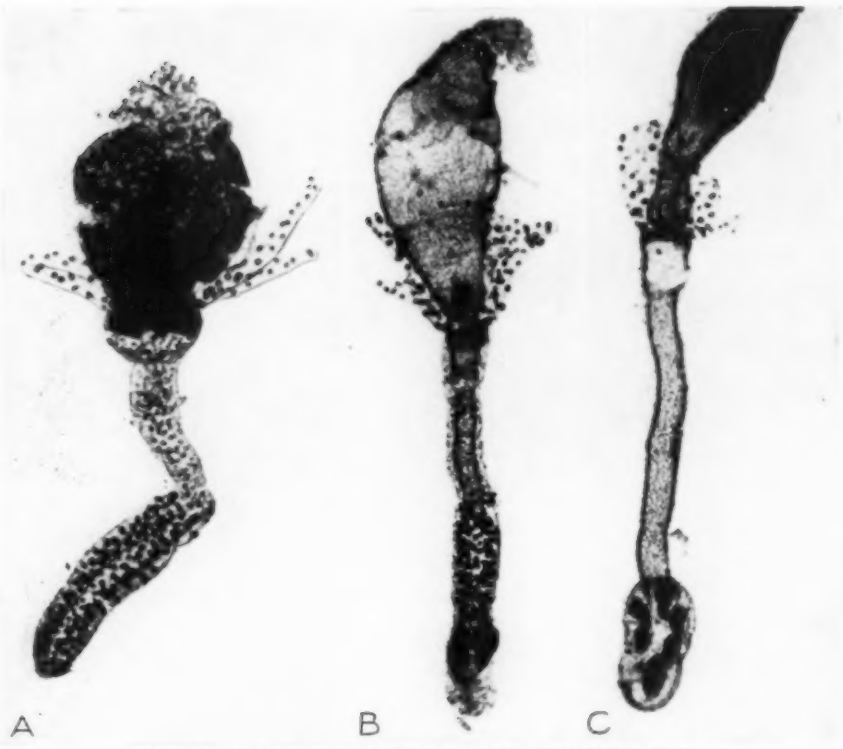
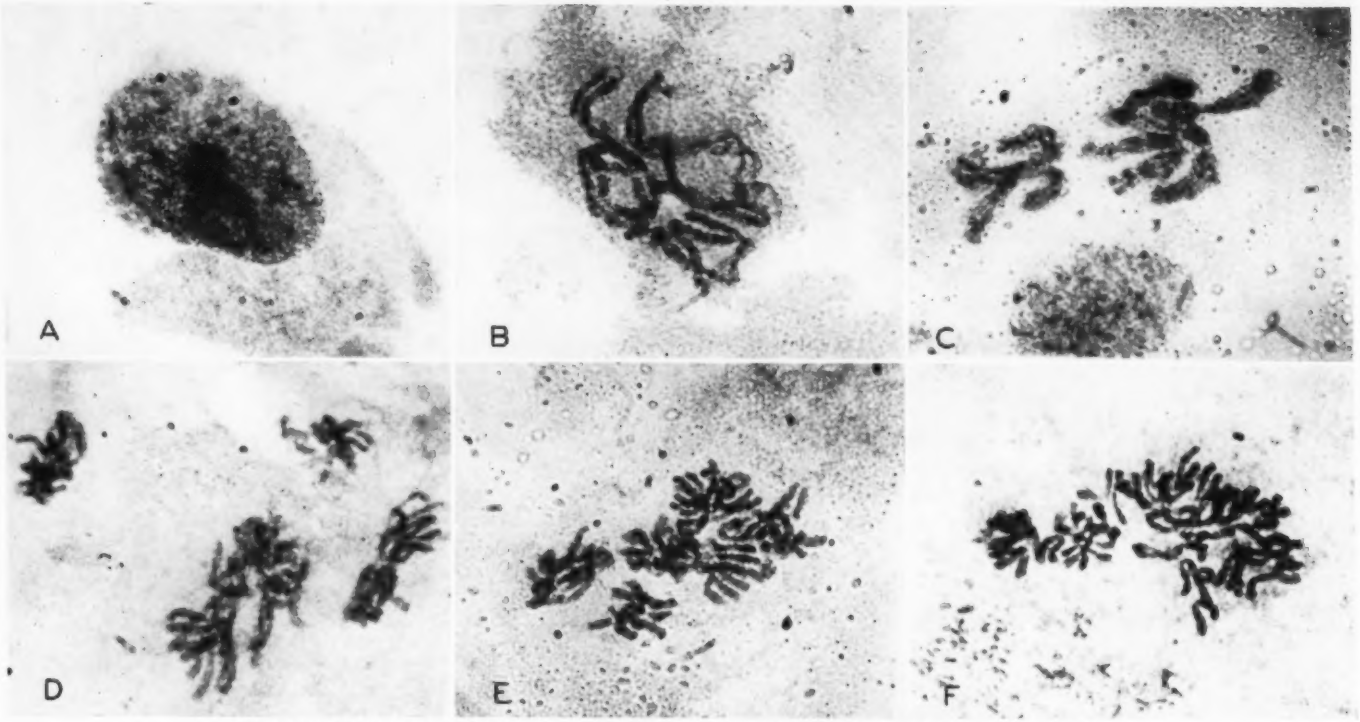


METAMORPHOSIS OF THE MOSQUITO HIND-GUT

Figure 8

A—Hind-gut of a young pupa before the beginning of metamorphosis. *B*—Hind-gut of a sixteen hour pupa with metamorphosis half completed, anterior and posterior cell migrations are invading the disintegrating colon. *C*—Hind-gut after metamorphosis; ileo-colon, rectal sac and papillae. During this metamorphosis the changes in chromosome number discussed in this article take place. Photomicrographs of Feulgen total mount preparations. Magnification 75 ×.

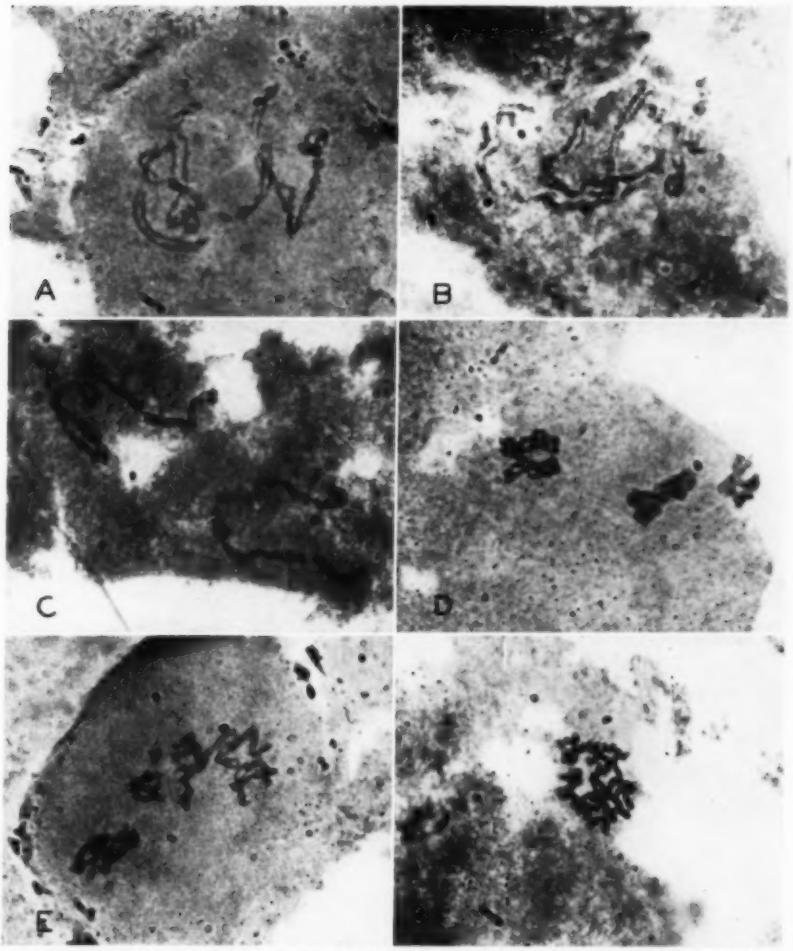
THE metamorphosis of the larval ileum of mosquitoes is accompained by several interesting cytological phenomena. As reported in earlier papers[1, 2, 3, 4, 5] the cells of the iliac epithelium increase in size but not in number throughout larval life. The increase in size is paralleled by an in-



PROPHASE STAGES IN THE DIVISION OF A NINETY-SIX CHROMOSOME CELL

Figure 9

A—Resting nucleus (*Aedes triseriatus*). *B*—Mid prophase (*Aedes canadensis*). *C*—Almost full prophase, contraction not completed (*Aedes triseriatus*). *D* and *E*—Late prophase (*Aedes triseriatus*). *F*—Metaphase, ninety-six chromosomes in forty-eight pairs (*Aedes canadensis*). All six photomicrographs are of aceto-carmine "smears" of the ileum. Magnification 940 ×.

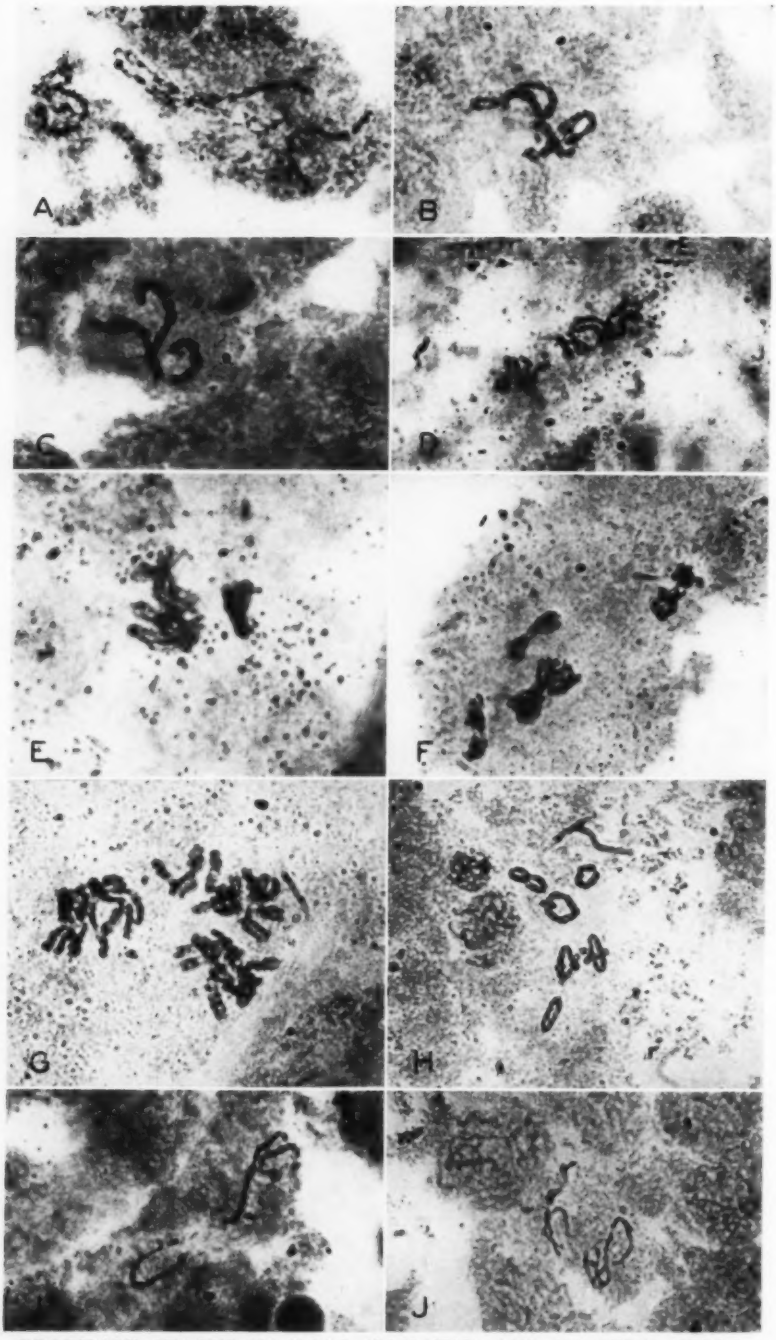


PROPHASE STAGES IN THE DIVISION OF A 48-CHROMOSOME CELL

Figure 10

A and *B*—Mid prophase, six group stage (*Culex pipiens*). *C*—Mid prophase, three group stage (*Culex apicalis*). *D*—Full prophase (*Culex pipiens*). *E*—Late prophase (*Culex pipiens*). *F*—Metaphase, forty-eight chromosomes in twenty-four pairs (*Culex pipiens*). All six photomicrographs are of aceto-carmine "smears" of the ileum. Magnification 940 ×.

crease in chromosome number from the diploid, six, to such high multiples as 48, 96 and rarely 192 chromosomes. The nucleus retains the typical resting stage condition throughout the growth and chromosome multiplication period. On account of recent developments in polyploidy, this situation in the mosquito has an increasing genetic interest. Here we appear to have multiplication of chromosomes within the resting nucleus. Subsequent divisions show orderly somatic synapsis and are apparently somatic reduction divisions giving smaller cells with a reduced chromosome number.



PROPHASE STAGES IN ILIAC (SOMATIC) AND IN GERM CELLS

Figure 11

A—Early prophase, probably twenty-four chromosomes (*Culex apicalis*). *B*—Mid prophase, probably twenty-four chromosomes (*Culex territans*). *C*—Mid prophase, probably

The bearing of these phenomena on the field of genetics and development is obvious. Possibly the multiplication of chromosomes described below may throw some light on the origin of the giant chromosomes, which are proving so useful in Drosophila and other diptera. In the one case we might have multiplication of chromatids *with* separation and in the other, multiplication of chromitids which failed to separate.

The process of metamorphosis may be readily understood by examining Figure 8. The condition of the larval hind-gut before metamorphosis is shown in Figure 8*A*. The wide, dark region is the posterior end of the mid-gut, filled with disintergrating larval mid-gut cells. The junction of the mid-gut and hind-gut is marked by the projecting ends of the Malpighian tubules. The hind-gut consists of a narrow anterior portion, the ileum, a wider region with very large cells, the colon, and a narrow and very short region, the rectum, not shown in the figure. The ileum is a double tube, consisting of an inner single-celled epithelial layer and an outer single-celled muscular layer.

Figure 8*B* shows the condition of the hind-gut when its metamorphosis is half completed. The epithelial cells of the ileum are undergoing rapid successive divisions, they are decreasing in size, increasing in number and are invading the anterior end of the colon. A similar migration of rapidly proliferating cells of the rectal epithelium is invading the posterior end of the colon As these two cell migrations advance the larval colon cells are shed into the body cavity where they disintegrate.

Figure 8*C* shows the hind-gut after metamorphosis. The colon has completely disappeared and a uniform tube, the ileo-colon, takes the place of the larval ileum and colon. At the posterior end a new structure, the rectal sac, is formed and contains the rectal papillae. Early indications of the rectal sac can be seen in Figure 8*B*. The epithelial cells of the ileo-colon are much smaller and more numerous than those of the larval ileum. Apparently each larval cell undergoes two or three successive divisions during metamorphosis. Indirect evidence has been presented in former papers[2, 5] which seems to justify the assumption that these divisions are somatic reduction divisions by which a decrease in chromosome number accompanies the decrease in size of the rapidly dividing cells.

At the end of the larval growth period the nuclei of the epithelial cells of the ileum are all large, but are not all of the same size. In the first cell divisions initiating metamorphosis high multiple complexes appear at metaphase. Complexes of 48 and 96 chromosomes are common and rarely cells with 192 chromosomes have been found. It is proposed in this paper to describe the nuclear changes occurring during the prophases of these divisions. For convenience four stages between resting stage and metaphase will be distinguished and designated as follows: early prophase, mid prophase, full prophase and late prophase.

Resting Stage. A typical resting nucleus as found in a large cell before metamorphosis is shown in Figure 9*A*. It is apparently composed of a number of long, thin, granulated threads. In places there are faint indications of

LEGEND TO FIGURE 11—Continued

twenty-four chromosomes (*Culex pipiens*). *D*—Very late prophase, twenty-four chromosomes in twelve pairs (*Culex apicalis*). *E*—Full prophase, probably forty-eight chromosomes (*Orthopodomyia signifier*). *F*—Full prophase, forty-eight chromosomes (*Culex pipiens*). *G*—Late prophase, forty-eight chromosomes, twenty-four pairs in three groups, note coiling and absence of chiasmata (*Aedes triseriatus*). Compare with Figure 9 *D* and *E*. *H*—First spermatocyte division (*Culex pipiens*), two cells, note clear chiasmata. *I*—Mid prophase of a smaller complex from the ileum, twenty-four or twelve chromosomes (*Culex pipiens*). *J*—Prophase of first spermatocyte division (*Culex pipiens*), three tetrads, twelve chromosomes. Compare with somatic prophases in *B*, *C* and *I* of this figure and with mid prophases in Figures 9 and 10. All protomicrographs are of aceto-carmine "smears" of ileum or testis. Magnification 940 ×.

fine lateral processes connecting adjacent threads but the general appearance is that of a mass of thin threads rather than of a reticulum. There is a nucleolus present.

Early Prophase. In early prophase a synapsis of sister threads takes place resulting in the formation of six bundles of long thin threads. The fact that six bundles are formed, corresponding to the diploid number, rather than three, is interpreted as evidence that the initial synapsis unites sister threads not homologous ones. It has been impossible to determine whether or not a contraction accompanies this synapsis since the length of the threads in the resting stage could not be ascertained.

Mid Prophase. This term is here used for the stage in which synapsis of sister threads is complete but contraction in length has not yet started. Figure 9*B* shows the mid prophase stage in a cell of *Aedes triseriatus*, the six groups of synapsed threads are loosely paired in three groups. The compound nature of each group and the parallel arrangement of chromomeres is evident in the figure. The loose pairing between homologous groups now becomes very intimate, so that in many cases it is indistinguishable from synapsis. At the end of mid prophase three groups of multiple prophase chromonemata are present, corresponding in number and size relationship to the haploid complex. Figure 10*C* and Figure 11*B, C, I*, illustrate the three group conditions in cells with different degrees of polyploidy. Compare these figures with Figure 11*J* which shows a prophase of a first spermatocyte division and hence is known to contain three tetrads. The occurrence of both a six group and a three group stage in mid prophase gives evidence of a primary synaptic attraction between sister threads and of a secondary attraction between homologous groups.

Full Prophase. After synapsis is completed contraction of threads takes place and results in six much shortened bundles usually arranged in three pairs. (Figures 10*D* and 11*E*.) Contraction is apparently correlated with a spiral coiling in each of the individual threads of the group. The coiling cannot be demonstrated at full prophase since the multiples are then very closely associated as well as being greatly contracted. However the clear coiling seen at late prophase and metaphase leaves little doubt that the assumption of the spiral structure is causally connected with contraction. Whether contraction is the cause of coiling or coiling the cause of contraction we have no means of deciding. The regularity of the spiral appears to favor the latter possibility.

Late Prophase. In the last stage of prophase each of the six full prophase groups falls apart into its constituent units, the unit being a synapsed pair of sisters in the first division and a synapsed pair of either sisters or homologues in later divisions. Homologous groups first separate as whole groups and while this is taking place the units in each group separate. As a result two striking chromosome arrangements occur. In the first of these, three groups of like units are seen as shown in Figure 11*G*. The second arrangement, as shown in Figure 9*E*, contains six groups of sister units. The units in the six group stage as well as in the three group stage each consist of two closely paired chromosomes. This condition is probably true of full prophase and of mid prophase but the threads are so thin it has been impossible to demonstrate their double nature. Considerations such as the amount of chromatin and the size of cells lead to the conviction that the photomicrographs in Figure 9 each represent a stage in the division of a 96-chromosome cell.

The six group condition is probably later than the three group stage and represents a more advanced state of the double separation process which involves groups as a whole as well as the units composing the groups. The late prophase separation is not always synchronous for all the groups. Figure 10*E*

shows a cell with the separation just beginning in one group while it is far advanced in the other groups. The same condition in a less extreme form is shown in Figure 11*G*.

When the separation of units is beginning each chromosome may be seen to have a loose spiral form. The metaphase chromosomes are about one-tenth the length of the mid prophase groups. Of this total contraction it is estimated that about 80% takes place from mid prophase to the end of full prophase. The remaining 20% of contraction can be accounted for by the closer approximation of the gyres of the spiral from late prophase separation to metaphase as shown in *D* and *F* of Figure 9.

Absence of Chiasmata. The synapsis of so many threads (16, 32 and 64) at full prophase would lead one to expect many and complicated chiasmata when separation takes place at late prophase. Such is not the case, the synapsed units fall apart with apparent facility and great regularity. Figure 11*H* shows two cells from the testis of *Culex pipiens* in the first spermatocyte division. The chiasmata in these cells are obvious but no figures bearing any resemblance to these were ever found in the prophases of the multiple complex cells of the ileum. One of the groups in Figure 10*D* may be interpreted as containing a chiasma but is by no means necessarily so interpreted. Chiasmata are not found in late prophase when they should be most evident. A comparison of Figure 11*H* with Figures 11*G* and *D* and 10*E* will make this point clear.

Discussion. The absence of chiasmata in these divisions favors the view that chiasmata in germ cells are the result of previous crossing-over rather than that crossing-over results from chiasma formation. Confirmation for this viewpoint may be had from the strong primary attraction shown by sister chromosomes and the weaker attraction of homologues.

The condition at mid prophase (Figure 9*B*) furnishes an interesting norm of comparison for studies on salivary gland chromosomes. In the prophases described in this paper we have multiple sister chromonemata in synapsis and closely paired with homologous groups. Such paired groups differ from salivary gland chromosomes in several respects. They are about ten times the length of metaphase chromosomes whereas the salivary gland type are about seventy times the metaphase length. The general appearance of the multiple prophase group is very different and there are apparently no achromatic regions. These cells can and do actually divide while the salivary gland type is incapable of division.

The pairing and synaptic phenomena shown in these prophases clearly contradict the theory that chromosomes are attracted only in pairs and that similar pairs necessarily repulse one another.

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Ludwig Plate's Last Volume

THIS is the final volume* of a comprehensive work on genetics and evolution planned and nearly completed by the late Professor Ludwig Plate. The two volumes dealing with the general and theoretical aspects of the subject

*Plate, L. Vererbungslehre mit besonderer Berück-sichtigung der Abstammungslehre und des Menschen. Bd. III, Sezielle Genetik einiger Nager. pp. 1233-1451, Figs. 255-297, 2 Pl. F. Fischer, Jena. Price 10 R M, bound 12 R M.

were published several years ago and were reviewed in this journal. The third volume was planned as a survey of knowledge of "heredity in the best investigated animals" other than Drosophila which had been extensively reviewed in volume II.

The chapters dealing with the laboratory rodents, mice, rats, guinea pigs and rabbits, had been completed but doubtless would have received further revision at the hands of the author had he lived longer. These chapters are now published as Plate left them, a preface being added by J. W. Harms.

The progress of science requires two kinds of activity, first the careful accumulation and recording of facts acquired by observation and experiment, second the comparative survey of such facts and their synthesis into generalizations. Plate spent most of his long life in this second line of activity, though he earlier made experimental studies of genetics in mice and in the war period on hairless dogs.

With great care and thoroughness he has reviewed the rapidly growing literature of rodent genetics, but a lack of acquaintance at first hand with the research material, most of which has been accumulated and studied in America, has allowed him to make some unfortunate mis-interpretations. Nevertheless the work will be useful as a guide in the study of mammalian genetics, though one who uses it will need to exercise caution and consult original sources directly when in doubt or faced with seeming contradictions.

The best of the reviews prepared by the author is that which deals with the genetics of rabbits where he has been guided by the excellent recent publications of Nachtsheim. The least satisfactory is that which deals with rats where no clear distinction is made between the genetics of *Rattus norvegicus* and *Rattus rattus*, two perfectly distinct species incapable of producing living hybrids. The known mutations of the two species are very different, but Plate confuses and interchanges them. Thus he assigns to *norvegicus* the white-belly allele of agouti which occurs only in *rattus*, and describes the dominant and the recessive black mutations of *rattus* as if they belonged to both species. He also fails to recognize that the yellow mutations of the two species are very different in nature. In *rattus* a yellow variety has arisen by a recessive mutation of the extension factor, analogous with the yellow varieties of rabbits and guinea pigs, but in *norvegicus* yellow varieties have arisen as modifications (not restrictions) of the black pigmentation, affecting eye pigmentation as well as hair pigmentation, analogous with the pink-eye mutations of mice and guinea pigs.

The sections of Plate's book which deal with the house mouse and Peromyscus are more satisfactory but perpetuate certain errors from earlier investigations. Thus pink eyed mutations are treated as members of the *E* (extension) series, where they do not belong, since retrogressive mutation in the *E* series results as a final stage in *dark eyed* yellows, never in pink eyed yellows. Pink eyed yellows result from a qualitative modification of black and brown pigments which affects similarly both coat and eye pigments. They occur in the house mouse, Peromyscus, the norway rat, and the guinea pig, but not in the rabbit or *Rattus rattus*. In the guinea pig and probably also in Peromyscus both sorts of yellow mutations occur in the same species, one producing a yellow coat with dark eyes through *restriction* of black pigment to the eye, the other producing a yellow coat by *modification* of black pigment so that it is scarcely distinguishable from yellow either in the coat or in the eye.

The two colored plates which Plate planned to illustrate color mutations of the house mouse are poorly labelled and incomplete, lacking altogether two figures which the original plan had included, so that the plates scarcely clarify a situation confused in the text.

The publisher with his usual flawless execution has done everything possible to remedy deficiencies but the touch of a master's hand is irreplaceable.

W. E. Castle
University of California

HEREDITARY OPALESCENT DENTIN

A Dominant Hereditary Tooth Anomaly in Man

HAROLD C. HODGE* and SIDNEY B. FINN

OPALESCENT dentin, a recently investigated anomaly of tooth development is characterized clinically by the extreme translucency, discoloration, friability, and wearing away of the teeth. The hereditary nature of this anomaly is observed in three unrelated families that form the basis of this study.

A cursory search through the literature fails to reveal, with few exceptions, any titles suggestive of this anomaly. However, its relatively high incidence in the population and the comparative absence of references to it in the literature suggests to us that the specific nature of this abnormality may have been overlooked. A careful analysis of reported hereditary tooth anomalies, not suggestive of a dentin defect, shows that the titles in many of these described cases are not consistent with the findings. The lack of any histologic, radiographic, or chemical studies together with their definite clinical similarity to the teeth reported in this paper has led us to assume that many of these abnormalities are opalescent teeth. Since hereditary opalescent dentin shows varying degrees of involvement, it is not surprising that this anomaly based upon purely clinical observation should be reported under many titles.

Guilford[1] as early as 1887 recorded the case of a man of 26 with crowns anterior to the molars worn level with the gum line, a condition which was traceable through three generations.

Talbot[2] described four generations of anomalous teeth whose crowns were completely worn to the gums. No pulp chambers were present and the pulp canals were partially obliterated. The dentinal tubules were absent at the cervical portion of the root and minute chambers persisted throughout.

Hereditary cases reported by Bennet,[3] Hopewell-Smith,[4,5] Holder,[6] J. S. Roberts,[7] Clark and Clark,[8] Fitton,[9] E. Roberts,[10] and Turner,[11] although reported under titles signifying absence, extreme deficiency, or hypoplasia of enamel, are probably, from their descriptions, cases of hereditary opalescent dentin.

Crownless teeth have been reported by Stainton[12] and by Bunting.[13] Their descriptions are very suggestive of opalescent dentin.

Abnormalities of tooth color and translucency recorded by Sinha,[14] Kaften,[15] Willett,[16] Moody and Montgomery,[17] Kessler,[18] and Keeler[19] are probably anomalies similar to the one which we have studied in this paper.

Wilson and Steinbrecher,[20] Noyes,[21] and Skillen[22] described dentin abnormalities, the latter under our title.

Genealogies

The genealogies of the three families studied, although not extensive, are sufficiently complete to illustrate the hereditary nature of this anomaly.

1. The *M.* family, of recent Italian descent, was first seen when Dominic applied for treatment at the Rochester Dental Dispensary. Upon examination of his mouth, this unusual condition of all the teeth was noticed. It was found that other members of the family were similarly affected as shown in pedigree (Figure 12*A*). There was some doubt about the five brothers and sister in Gen-

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eration III since it could not be remembered whether they were or were not affected. No verification could be made as they all reside in Italy. The mother remembers only that one sister had a similar type of tooth defect. Since she well remembers affected individuals, it is highly probable that the doubtful brothers and sisters in Generation III are normal. The family shows four generations with three matings producing 9 females and 7 males, 9 affected; 1 known normal and 6 unknown. The offspring are divided as follows: male affected, 3; female affected 6; male normal, 0; female normal, 1 unknown: male 4, female 2. The identical twins in Generation IV are counted as 1.

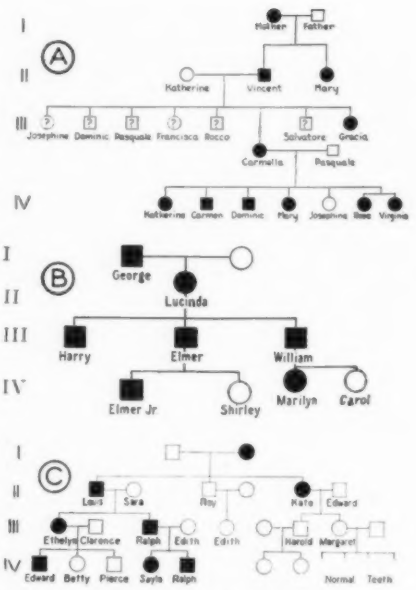
2. The *S.* family, of German-Irish descent, was first seen about a month after the *M.'s* when Elmer, Jr., applied at the Rochester Dental Dispensary for treatment. Upon examination of his mouth, a striking similarity was observed between his teeth and those of the *M.* family. Inquiry proved this condition to be hereditary as shown by the pedigree (Figure 12*B*). The *S.* family shows four generations with four matings resulting in 4♀:4♂; 6 affected: 2 normal. They are divided as follows: male affected, 4; female affected, 2; male normal, 0; female normal, 2.

3. The *C.* family, of American stock, has resided in China and India where they are missionaries. The pedigree of this family along with the extracted teeth of Sayla were submitted to us by Edith C. Leanord of Scotia, New York, for study. Their pedigree is shown in Figure 12*C*.

The sex of the children born in India (F_4) was not indicated (all normal). The *C.* family presents four generations with eight matings resulting in 8 females and 7 males, 4 sex unknown; 7 are affected and 12 are normal. They are divided as follows: male affected 4; female affected, 3; male normal, 3; female normal, 5; normal, sex unknown, 4.

Tabulating the above data we get the totals shown in Table I.

From these figures it can be seen that the defect behaves as a typical dominant characteristic and does not show any sex linkage. Individuals who possess the defect mated with normals transmit the defect to approximately



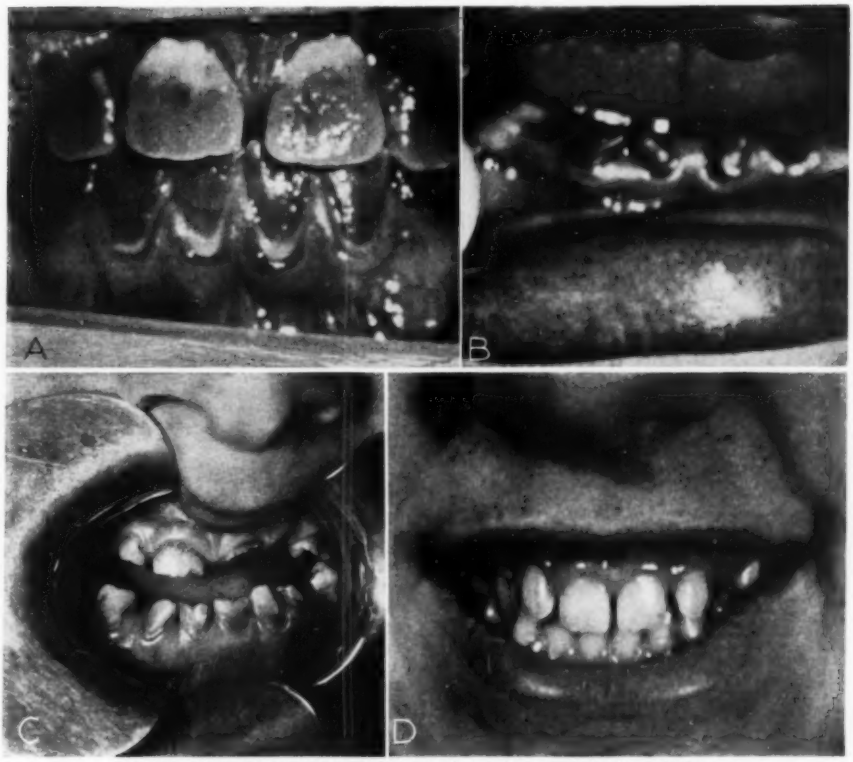
INHERITANCE OF OPALESCENT TEETH

Figure 12

Pedigrees of the *M* family (*A*), of the *S* family (*B*), and of the *C* family (*C*). All three pedigrees indicate that a single Mendelian factor is involved, opalescent dentin being dominant.

TABLE I. Summary of matings between affected and normal individuals.

	Generations	Matings	Affected		Normal		Unknown	
			♂	♀	♂	♀	♂	♀
M.	4	3	3	6	0	1	4	2
S.	4	4	4	2	0	2	0	0
C.	4	5	4	3	3	2	0	0
Totals	12	12	11	11	3	5	4	2



OPALESCENT DENTIN IS SOFT AND TRANSLUCENT

Figure 13

A—Opalescent teeth present a high degree of translucency as observed in the incisors of Dominic M. *B*—The lower incisors of Lucinda M. Notice complete absence of crowns produced by the wearing away of the extremeuy soft teeth. *C*—In another family, E. S., Jr., has extremely friable opalescent teeth, but his sister, Shirley (*D*), has normal teeth. The opalescent teeth are much softer and more easily discolored than normal teeth, as is clearly brought out in the photographs.

half their children. The three families studied show 12 matings between abnormals and normals. These produced 36 children—22 abnormals and 8 normals, six unknown. The normals did not transmit the defect in two matings of normal sibs of affected with normals, producing 6 normal offspring. The affected individual would therefore be heterozygous for this factor. In marriage of heterozygous dominants with normals, we would expect to get equal numbers of normal and affected offspring. This is not the case. The excess of affected individuals might be explainable by the little significance attached to the normals by the reporting families and their failure to report them with equal accuracy. This tendency for human pedigrees to show an excess of affected has been noted by many workers. In this series, the small population, and the large number of unknowns complicates statistical evaluation. If we assume that two-thirds of the unknowns are normal, the deviation from equality would not significantly exceed the probable error so that simple Mendelian inheritance accounts satisfactorily for the available facts.

We have found that the intensity of the pathology varies in different mouths. This would seem to indicate in all probability that the inheritance is not a simple one, but that there are quantitative modifying factors. There is also the possibility that in the production of this abnormality entirely different sets of factors may be working to produce comparable results.

General Clinical Findings

The clinical examination was made as thoroughly as possible. Except for the anomaly of the teeth, the physical examinations gave normal findings. A thorough dietary history revealed only that the *S.* family has a good well-balanced diet and that the *M.* family had a restricted and questionably adequate diet. It is probable therefore that the diet has little or no influence on the condition. The basal metabolic rates vary from +15 to —15, with most of the values normal. A complete differential blood count was made on each patient giving normal blood pictures in every case. Wasserman examinations gave uniformly negative results. A chemical and microscopic urinalysis of each patient gave normal values. Blood chemistries on each patient gave normal values for calcium, phosphorus, blood sugar, and total cholesterol. The only consistently abnormal clinical finding was the high values for the plasma phosphatase in the children. The values for the adults, 5 and 7, are normal values. The values for the children aged 11-16 range from 9.5 to 17.5; for the children from 3-9, the values range from 13 to 23.5 — values two to five times the normal range. It is interesting in this connection to note that those diseases in which a high plasma phosphatase occurs are the bone destroying diseases such as osteomalacia, rickets, osteitis fibrosis cystica, and osteogenesis imperfecta. No demonstrable changes, however, could be observed in the skeletal radiographs. Although the finding of high plasma phosphatase concurrently with badly hypoplastic dentin may offer some clue as to the degenerative nature of this anomaly, we are of the opinion that the high plasma phosphatase value may be produced by an independent genetic factor. The high plasma phosphatase values in the children *not* showing this tooth anomaly lend verification to this belief.

A complete salivary study both chemical and bacteriological gave only normal findings.

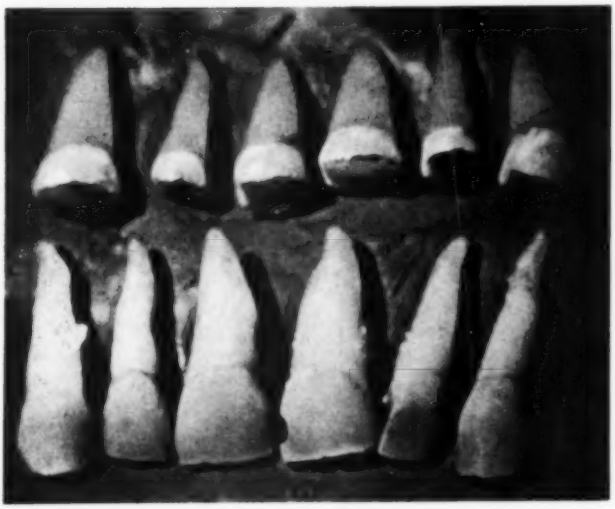
Oral Clinical Findings

Opalescent teeth are distinguished by their high degree of translucency (Figures 13*A* and 13*C*) and their peculiar refractive property which frequently shows a play of colors difficult to define and which suggested to us the title of "Opalescent Teeth." There is a softness of the dentin that makes the teeth subject to rapid and excessive wear (Figure 13*B*). In areas denuded of enamel, the dentin, which is extremely hypoplastic, varies in color from yellow to a deep brown depending mostly upon extrinsic staining. The dentoenamel junction does not appear normal. This, together with the softness of the dentin renders to the tooth, and especially to the enamel, a high degree of friability (Figure 13*C*). The enamel has a grey to bluish brown hue although showing almost no pigmentation. The teeth have a low caries susceptibility, although the mass destruction of the crowns and their early excessive wear often simulate rampant caries. The oral mucosa appears normal.

Radiographically, the crowns, allowing for attrition, are of average size. The root size is decreased (Figure 14). Pulp chambers are absent, and pulp canals are completely or partially obliterated. The roots are prone to fractures, and there is a tendency to formation of apical abscesses. The peridental membrane is of normal thickness. The alveolar bone is not abnormal.

Microscopic Structure

The histologic study of ground and



OPALESCENT AND NORMAL TEETH

Figure 14

Contrast the short blunt roots and extreme wear of opalescent teeth (Sayla *C*) with those of normal teeth (below). Chemically the opalescent dentin resembles compact bone more than it does normal dentin.

decalcified stained sections shows a more or less structureless dentin and normal appearing enamel. The enamel in ground sections, observed under polarized light, presents normal, well outlined enamel rods. The dentin shows great variation in structure pattern. It varies from the extreme absence of tubules and an irregularly granular matrix to a fairly normal appearing dentin with a relatively normal tubuli pattern in the mantle layer. The course of the tubules shows extreme variation, in some instances running at right angles to the usual course. The pulp chambers and canals are totally or partially obliterated. One finds, instead, greatly enlarged, sagittally placed tubules. At times it is difficult to tell whether they are enlarged tubules or pulpal inclusions. The size, direction, and location of these sagittal tubules are reminiscent of the so-called "osteodentin" described in the teeth of certain lower forms, e.g., sharks' teeth. The cementum appears normal, varying only slightly in thickness and irregularity about the different teeth. Under high magnification, the cementum has a normal lamellar structure with typical lacunae.

Chemical and Physical Properties

Opalescent teeth show an abnormally high water content and low inorganic content, but the inorganic residue has normal percentages of calcium and phosphorus. In whole teeth, the water content ranges from 17 to 21—normal 8.9; the inorganic content ranges from 72 to 78—normal 84.8. Based on inorganic content, the calcium is about 35 per cent, phosphorus 17 per cent, and calcium to phosphorus ratio 2.05, all normal values. Enamel analyzed separately gives normal values of about 2 per cent water, and 96 to 98 per cent inorganic. Dentin analyzed separately gives values of about 25 per cent water —normal 15 to 18 per cent; and inorganic content 60 per cent—normal 70 to 80 per cent. In general, the chemical constitution of opalescent dentin is much more like compact bone than like normal dentin.

The average density of opalescent dentin is 2.07 as compared to 2.14, the average density for normal dentin. This density difference might be expected since opalescent dentin contains more water and organic matter than normal.

Hardness tests produced by cutting the tooth surface with a diamond pointed needle shows opalescent dentin to be much softer than normal dentin: opalescent dentin 72, average normal 130 microhardness units.

The average interpolated x-ray ab-

sorption value per unit thickness of opalescent dentin is about 0.65—normal 0.95. The interpolated value per unit thickness of enamel on opalescent teeth is about 1.3, a normal value. Since the x-ray absorption is dependent almost entirely (about 90 per cent) on the calcium content and since opalescent dentin has a low inorganic per cent, the low average absorption value might have been expected.

An x-ray diffraction pattern of opalescent dentin shows that the molecular structure of the inorganic portion of the tissue is the same as that of normal teeth. The pattern is that of hydroxylapatite, the principal inorganic constituent of all the calcium phosphates of the body. Since tooth substance, bone and pathologic calcifications all show this structure, it is not remarkable that opalescent dentin also consists principally of this substance.

Enamel of opalescent teeth under polarized light shows complementary color changes when the tooth is rotated between the crossed Nicol prisms. This is a normal finding. However, opalescent dentin gives no symmetrical color patterns nor differences between opposite sides of the tooth as does a normal tooth. It appears almost structureless with tiny areas of complementary colors side by side throughout the dentin.

Acknowledgment

The direction and assistance of Dr. Curt Stern in treating the genealogical data is especially acknowledged. In publishing this summary of a correlated clinical and structural study, the authors are abstracting the work of many collaborators. In the detailed presentation to be made elsewhere, full credit will be given to them. The authors acknowledge the work of the following: discovery of the families—G. B. Lose and H. B. G. Robinson; clinical histories and physical examination—S. H. Bassett and F. S. Gachet; basal metabolism—K. Morgareidge, D. Jamieson and A. McCoord; blood chemistry—A. McCoord; blood counts—D. Culliton; urinalysis—R. C. Robb and M. Gerbasi; saliva analysis—R. E. Brawley; histological—H. B. G. Robinson; x-ray absorption—G. Van Huysen and C. Du Pont; density—R. S. Manly; x-ray diffraction—W. F. Bale; chemical analysis—M. L. LeFevre; consultation on genetics—R. C. Robb and Curt Stern; and photography—H. Henn and W. Schusterbauer.

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MERLE OR CALICO FOXHOUNDS

J. McI. Phillips and E. D. Knight

COLLIES, Shetland Sheep Dogs, Old English Sheep Dogs, Norwegian Dunkerhounds, Great Danes and Dachshunds are often found in the pattern of color known among dog breeders as merle. Mitchell[1] has called this color dominant dilution. The color can be described as faded in some areas and full color in others. The areas of full color have a marbled or mottled distribution. The light areas look quite like the coat of dogs homozygous for the dilution factor *d*. In some instances these light areas are peppered throughout with varying numbers of white hairs. In Great Danes, unlike the other breeds mentioned, the color seems to be very closely associated with the dominant factor *H* described by Little[2] as occurring in this breed. Its exact relationship has not been determined, but merle specimens are commonly seen both in litters of harlequin by harlequin and in litters of harlequin by solid black (*BBEE*). Merle spots are almost always found on harlequin dogs in addition to the solid color patches. As these are practically the only combinations used by harlequin breeders the results of other types of mating are unknown to us.

The inheritance of merling resembles the blue of Andalusian fowls and the roan of Shorthorn cattle. Animals homozygous for the factor are white with slight areas of color which are found chiefly on the head and ears but may be found on other parts of the body also, while those heterozygous for the factor are merled, and when the factor is absent full color results. Merle dogs often have a china eye; but when the dog is homozygous various abnormalities of the eye are found, both eyes are usually china or blue. In rare instances one may find a considerable amount of pigment in the iris. Other ocular defects are very common. Wriedt[3] calls attention to the presence of irregular pupils which we have also observed in Danes. Mitchell mentions the almost complete unilateral absence of an eyeball with blindness in the Collie. Homozygous merles are invariably deaf, and deafness is quite common in the heterozygotes. In this type of dog deafness may be incomplete, so that he pays attention to loud noises and his owner believes that he hears but is a "pig-headed" dog. Full color dogs of merle ancestry sometimes have china eyes. Dominant spotting in horses is often associated with this eye condition, but hearing defects have not been noted[4]. White female individuals in Shorthorn cattle are often sterile, the sterility being due to an incomplete development of the vagina. This condition is very rare in other breeds of cattle and in Shorthorns other than white. Veterinarians know it as imperforate hymen or "white heifer disease." We have not heard of deafness or eye defects in these Shorthorns.

The dominant dilution factor may affect any full color or recessive dilutions of these due to the factors *dd*. For example in Collies both tricolors and sables may show it; in Dachshunds we find blue, chocolate, and golden merles which are called dapples in England and tigers in Germany[5], and among Great Danes where recessive dilution is found, a very washy variety of merle without any full color spots sometimes crops up.

The marbled pattern in orange or yellow dogs is often very obscure, but these dogs almost invariably have bilateral or unilateral china eyes, or at least some flecking of an iris with blue spots. This is commonly encountered in washy sable Collies and Shelties where the red pattern is due to the dominant A^y factors; and in light red hounds homozygous for *e*.

In dogs where merle occurs it is often associated with ordinary recessive spotting *s*. When merled animals are homozygous for recessive spotting the white splashed areas follow their usual pat-

tern, so that merle Collies have the white collar, ruff, blaze and points which are seen in ordinary piebald animals. It is interesting to note that there is also a very definite linkage between extreme developments of piebald spotting and china eyes and deafness. The breeds where this is best shown are white Collies with deafness and Bull Terriers with both china eyes and deafness.

China eyes and deafness either associated with or independent of each other are very common defects in Dalmatians or Coach Dogs, but merles and whites with defective eyes and deafness do not occur, although many litters will contain some individuals with extremely small spots, and these may be limited in their distribution. This breed has a peculiar polka dot pattern found in no other breed, which is usually considered a dominant form of spotting similar to that known as the English pattern in rabbits. However, when these dogs are bred to dogs homozygous for self color and black the offspring are all solid black, but when bred to ordinary piebald dogs with plain white areas the F_1 will show the white areas flecked with colored dots. This would seem to indicate that the Dalmatian spotting is recessive to solid color and closely allied to, but distinct from the ticking factor found in many breeds such as Setters, Cockers[6], Hounds, etc.

The occurrence of merle in American Foxhounds has not been previously reported in the literature. In the localities where it occurs they are called calico hounds and there is a general superstition that dogs of this pattern are usually tough. This is probably without foundation.

A pair of these calico hounds, sibs, by a black and tan Trigg hound out of a cream calico July bitch[7] recently came to our attention in a Bench Show. Investigation disclosed the fact that they were originally from the kennel of Mr. Alanson Trigg, III, and Mr. Paul Greer of Glasgow, Kentucky, who had given them to the late Mr. Thatcher A. Parker. Mr. Greer still maintains the kennel of Trigg hounds. He writes as follows:

CALICO FOXHOUNDS

Figure 15

Male (*A*) and female (*B*) calico foxhounds. *C*—Calico pups of dog shown in *A*, with their black-and-tan dam.

"As to the 'calico' color, that comes from the July strain of hounds. We have made a few crosses with the Trigg and July and part of the litter would be this color." He also states that they have no more endurance than hounds of other colors.

Before the introduction of the July cross Trigg hounds were mostly the saddled black and tans with white ring

necks and points, but there were some other hound colors in the pack. Calicos have now been eliminated. Attempts to obtain information about the origin of this color in the July pack were unsuccessful but Mr. George Garrett of Midland, Georgia, writes that this information will be included in a book entitled *Fifty Years with Fox and Hound* which is about ready for the press.

This pair of calico hounds were without piebald splashing and the color under the merle was black and tan of the ordinary blanket pattern. They had dark eyes and good hearing. When mated they produced three calico hounds with a great deal of white, all of which had china eyes and were deaf; one calico hound with one china eye and a suggestion of white on the toes of the forefeet, also deaf; and one sound full color with dark eyes. This dog was "pig-headed" and may have been hard of hearing. Mated to a bitch with the black saddle or blanket on a tan background, and with no piebald splashing, the male dog of this pair sired two well marked black and tan calicos. One of these had one china eye and one dark one, while the other had two dark eyes, both had good hearing; another calico pup, a tan merle, was deaf and had china eyes; the other three puppies in this litter were full color, two self tans and one black and tan without white. All the full colored puppies had dark eyes and good hearing.

From other Foxhound breeders we have learned that the calico by calico matings will sometimes produce a defective white, but that deaf dogs with a large proportion of white and both eyes china are found in every litter.

Summary

The merle pattern of Foxhounds is very similar in its behavior to the merle pattern in other breeds which have been studied. It cannot be bred pure because when homozygous the progeny are deaf, china eyed, and too light in color. Apparently the homozygous merle Foxhound carries more color than other homozygous merles. In the heterozygous state it can affect either black and tan or plain tan (where it is often overlooked) to make the calico pattern. Deafness due to a recessive factor is apparently linked with the factor for calico color.

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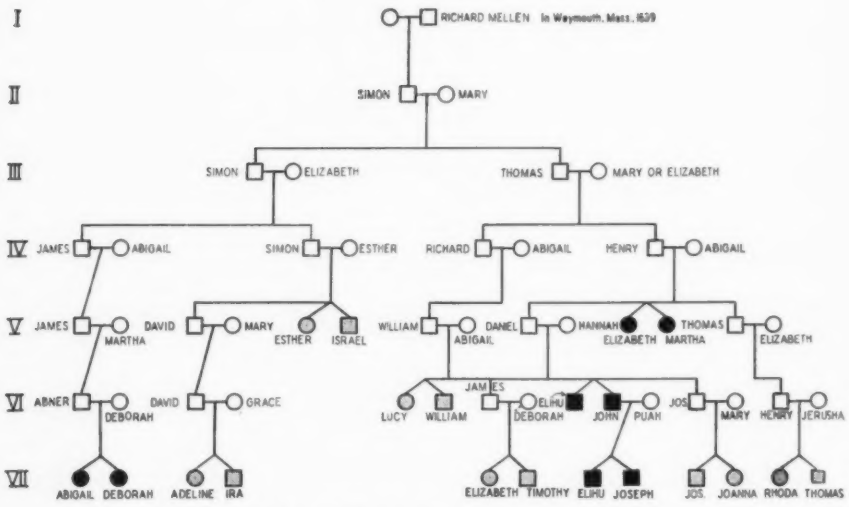
◆

TEN PAIRS OF TWINS

By Ida M. Mellen

A RECENT elaboration of the Mellen Family Chart from many books of town history and genealogy which were not available when the Chart was originally compiled in 1917, revealed the remarkable occurrence of ten pairs of twins within three generations. They descend solely through the male line, all having the same surname. No girl in the family ever produced twins.

If we call Richard Mellen "Generation 1" (he was the first of the name in this country, having taken the Freeman's Oath in Weymouth, Massachusetts, September 7, 1639), we may say that during the first four generations



TEN PAIRS OF MELLEN TWINS

Figure 16

In the first three generations of Richard Mellen's descendants there were no twins. In the next four generations there were ten pairs. In the four generations since generation seven of this chart no more twins have been recorded. Why should the eighteenth century have been a high-twin century in this family when before and after that time no twins were born? (Black symbols mark twins of the same sex; shaded symbols twins of different sex.)

there were no twins. During the next three generations ten pairs occurred, and during the four generations which have followed these, there have been no twins.

Four pairs of twins may have been identical—Elizabeth and Martha, Abigail and Deborah, Elihu and John, and Elihu and Joseph—two pairs of girls, two pairs of boys. This leaves the sexes even for the ten pairs, ten girls, ten boys.

Only one twin sired twins. He was John Mellen, the twin of Elihu, Generation 6, who married Puah Fisher. John's twin, Elihu, died childless. John's twin children were the boys Elihu and Joseph.

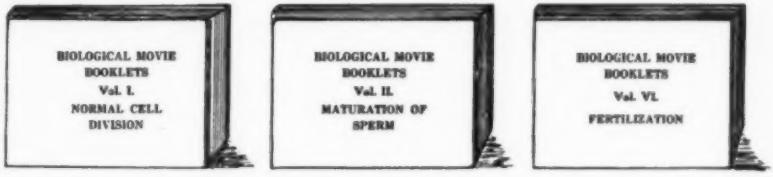
In no case did more than one pair of twins occur in the same family, though in one family the children numbered eleven, in two families ten, in two families nine, in two families seven, in two families six, and in the remaining family there were four. Of the seventy-nine children in these ten families, therefore, twenty, or slightly more than one-fourth were twins.

What caused this sudden outbreak and sudden cessation of twins we cannot even conjecture, but can only offer the facts for correlation with other facts which eventually may combine in yielding a solution.

THE BIOLOGICAL MOVIE BOOKLETS

DRAWN BY

DR. CLYDE E. KEELER



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922 Checkerboard Square, St. Louis, Mo.
Please send sample of Rabbit Chow and bulletin giving ingredients, cost and feeding directions.

I keep about (No.)..... guinea pigs; ..... rabbits

Name..... *Dept.*.....

Institution..... *Address*.....

The American Genetic Association

An incorporated organization devoted to promoting a knowledge of the laws of heredity and their application to the improvement of plants, animals, and human racial stocks.

Its membership is composed of men of science, teachers, publicists, physicians. clergymen, parents, students, horticulturists, and breeders of live stock throughout the world.

The Association owns the JOURNAL OF HEREDITY, which is published monthly and sent to each member without additional cost. Every member is thus a part owner of the JOURNAL.

Membership imposes no burdensome obligations. The Association, which is co-operative in nature, welcomes assistance in research, but does not demand it. Members are invited to submit discussions of the results of their research, accompanied by new and unusual photographs. All papers received will be given full consideration by the editorial board.

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